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NUCLEAR POWER PLANT SITING STUDY

for

DEPARTMENT OF THE ARMY

OFFICE, CHIEF OF ENGINEERS

WASHINGTON, D.C.

VOLUME II

Submitted by

united engineers
& constructors inc.

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The report presents the criteria and methodology for evaluating the siting of a nuclear power plant at Radford Army Ammunition Plant (RAAP) near Radford, VA. A detailed plant design is described utilizing the Process Energy Consolidated Nuclear Steam Generator (PE-CNSG) concept developed by the Babcokck and Wilcox Co. The PE-CNSG is a 313 MWt pressurized water reactor with 12 modular once through steam generators located inside the pressure vessel. For this application it has been configured to export 570,000 lb/hr of steam and 23 MW of electricity. Three candidate sites at Radford were evaluated and one site was selected as

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Having the most favorable overall characteristics. This site was further evaluated and found to viable based on supporting data.

An economic analysis was performed comparing the PE-CNSG to an equivalent coal-fired plant. The report concludes that at the expected utilization level of 45% of full mobilization requirements the nuclear system has a slight economic advantage versus the coal system. This advantage is increased at higher levels of production. No technological or sociological barriers which would preclude the implementation of the nuclear system were identified.

SECTION 3: PLANT DESIGN AND COST ESTIMATE

3.1 Site Description

The plant site, Site 3, discussed in Section 2, is located at the north end of a hill bounded by the Stroubles Creek on the north and east and by Geese Creek on the west. The terrain along the plant north-south direction varies from elevation 1,850 feet to elevation 1,930 feet in approximately 800 feet. The slopes of the hill flanks adjacent to the site are very steep varying from 1:1 to 1:3. East of the site adjacent to the Stroubles Creek is located State Route No. 114.

Drawing 6390.002-S-001 shows the site topography; a detailed description of this site including subsoil investigations have been discussed in Section 2.

3.1.1 Site Development

3.1.1.1 Earthwork

Earthwork is proposed to create three (3) plateaus as follows:

Plateau No.	Purpose	Nominal Elevation	Acreage
1	Main plant buildings	1,850'	5
2	Cooling towers	1,880'	2
3	On-site construction fac.	1,920'	9

The plateaus listed above require substantial earthwork consisting of approximately 330,000 c.y. of soil, 45,000 c.y. of soft shale and 100,000 c.y. of hard shale excavation. The soil excavation is planned to be done with the use of bulldozers, blading the soil to each side of the site. The soft shale excavation is expected to require a ripping operation prior to blading. The hard shale excavation is expected to require blasting prior to blading by bulldozers to each side of the site. No dewatering is expected to be necessary because of the well drained condition of this site. A siltation pond with intercepting

ditches will be required during construction to preclude the siltation of existing streams and rivers. This siltation pond is proposed to be located south and adjacent to the Stroubles Creek, northwest of the plant site.

3.1.1.2 Site Access

Rail access is not proposed for this site due to technical difficulties and high costs which are imposed by the site's topography.

The trend of transportation of construction material by truck has been increasing in the past decade because of greater reliability. Also, fuel and materials required during plant operation can be transported by truck. Therefore, only road access is proposed for connecting this site to State Route No. 114. Furthermore, improved security results from only one means of access.

3.1.1.3 Construction Facilities

A plateau at elevation 1,920 feet with an area of approximately nine acres is proposed for the following onsite construction facilities:

- Change house
- Main office
- Construction parking
- Subcontractor trailer area
- Toilet and wash house
- Sewage treatment plant
- Pipe shop
- Electrical shop
- Temporary power substation

An area measuring approximately 100 feet x 225 feet is provided near the reactor building for liner fabrication. Another area of approximately 21 acres is required for the following off-site construction material storage and facilities:

- o Batch plant
- o Rebar laydown
- o Lumber yard
- o Pipe storage
- o Warehouse
- o Gas and diesel pumps and tanks
- o Cable yard

This off-site construction area is proposed to be located north of State Route No. 114, adjacent to the site access road.

3.1.1.4 Foundations

The main plant building and structures are proposed to be founded on rock.

3.1.2 Implications of Site 3 on Plant Cooling System

Due to the elevation of Site 3, the choice of cooling systems must be carefully made on the basis of parameters such as the pumping power required for a once through cooling system versus the cost of cooling towers. This choice is discussed in detail in subsequent sections. In addition to the above, certain changes have been imposed on the PE-CNSG-Reboiler-TG design as originally conceived by B&W (Reference 1). These changes are discussed in subsequent sections as well. These modifications are only applicable to the secondary systems; the NSSS itself and related nuclear systems have remained unchanged.

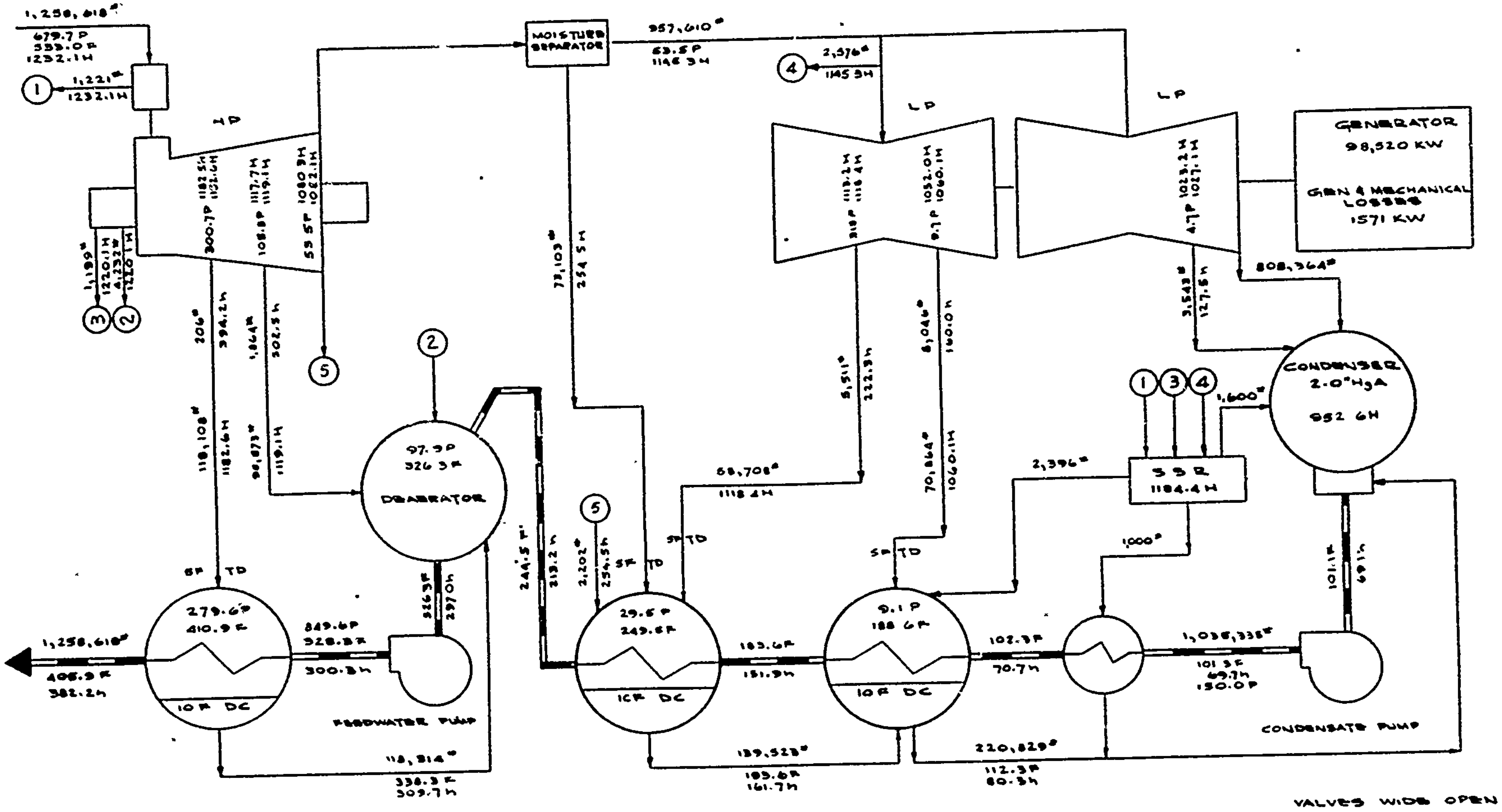
3.2 PE-CNSG Technical Description

3.2.1 Basis for Present Plant Design

The Radford plant is based on the land based PE-CNSG concept developed by the Babcock and Wilcox Company in conjunction with UE&C under ERDA Contract E(11-1)-2477 as described in Reference 3-1, A Small Pressurized Water Reactor for Process Energy. In that effort, UE&C developed two separate land based conceptual designs to produce 1,090,000 lbs/hr process steam in one case and 91 MWe electricity in the other case, both at the Middletown Site. For each, capital costs, operating and maintenance costs, construction schedules, and overall balance of plant, including a wet versus dry refueling scheme evaluation and a seismic analysis of the overall PE-CNSG loadings were developed.

NSSS Description

The PE-CNSG NSSS is a 313 MWt pressurized water reactor with a set of 12 modular once-through steam generators and an oversized pressurizer. The steam generators are positioned inside the reactor vessel in an annulus above and radially outside the core. The pressurizer is an external, electricity heated vessel connected to the reactor by a large surge line. The reactor vessel is a thick-walled, stainless steel clad, carbon steel vessel measuring 157 inches in diameter and 34 feet, 8 inches from head to head. The reactor core consists of 57 fuel assemblies of 200 zircalloy-4 clad fuel rods each arranged in a 15 x 15 array. Each assembly has an active fuel length of 72 inches. Each fuel rod has a diameter of 0.430 inches. The array includes 24 control rod guide tubes, which can accommodate a movable control rod guide assembly, a burnable poison rod assembly, or an orifice rod assembly to reduce bypass flow. The reactor is controlled by 17 control rod assemblies which are powered by their respective CRDMs. Control rod scram insertion is by gravity.



NOTES
H, h - ENTHALPY BTU/LB
- FLOW LB/HR
P - PRESSURE PSIA
F - TEMPERATURE, °F

GROSS HEAT RATE = $\frac{1,258,618\,(1232.1 - 382.2)}{98,520}$ = 10858 BTU/KW HR

VALVES WIDE OPEN

HEAT BALANCE DIAGRAM
MWe CNSG
MIDDLETOWN HYPOTHETICAL SITE
6255-005

FIGURE 3-1
7-15-75

The reactor coolant system incorporates four vertically mounted wet-motor single stage pumps having a combined capacity of 18,950 gpm at 106 feet of head. Twelve modular once through steam generators each with 933 one-half inch (OD) Inconel tubes are arranged in a circle inside the reactor vessel.

Reactor containment is provided by a free-standing, bottom-supported steel cylinder 38 feet in diameter and 67 feet high with an upper elliptical head. This section includes a removable center piece for refueling as well as for installation and servicing of reactor components.

Electric Plant

For the NSSS and under the contract described above, UE&C developed the balance of plant conceptual design for an electric generating plant which converts steam from the secondary side of the steam generator of the PE-CNSG into electric power. To assure system compatibility with the steam conditions of the PE-CNSG, turbine generator suppliers were contacted. General Electric Company proposed a 3600 rpm tandom, compound form flow steam turbine with direct coupled 105,000 KVA, 3600 rpm, three phase 60 Hertz, hydrogen-cooled synchronous generator in congruence with a heat balance. From the turbine design information, heat balance, and cost information also presented by General Electric, the main and supporting systems, building design and arrangement, and costs were developed. See Figure 3-1 for the electric generation heat balance diagram.

Process Steam Plant

The secondary system process steam plant developed by Babcock and Wilcox employed U-tube reboilers to transfer heat from the secondary side of the steam generators located within the reactor pressure vessel to the tertiary or process steam system. The B&W-designed reboilers were designed for secondary

steam from the PE-CNSG condensing in the tubes and process fluid being heated on the shell side. Secondary steam entered the reboilers at 700 psia and 538°F (35°F superheat) and exited slightly subcooled at 675 psia and 497.4°F with a total flow rate of 1,254,000 lbs/hr. See Figure 3-2.

The tertiary or process system, again developed by B&W, was designed as a closed system with condensate return to the reboiler train under the assumeed conditions of 250°F and atmospheric pressure. The feedwater system under these conditions was designed for dearation and pressure boosting by feedwater pumps before entering the shell side of the feedheater which would raise the temperature from 250°F to 367.2°F for preparation for entry to the reboilers. Process steam under these conditions was designed to exit the reboilers at 482.6°F and 580 psia at a flow rate of 1,090,000 lb/hr. See Figure 3-3. wer overall system thermal output results if process condensate is not retu at the assumed conditions.

Furthermore, the tertiary system design was based on the assumption that process condensate is available at a purity described in Appendix F, Table 1 of Reference 3-1. If condensate does not meet the purity requirements, additional water treatment facilities would have to be provided.

Utilizing the above described Babcock and Wilcox designed NSSS/Reboiler System for process heat, UE&C developed the preliminary conceptual design for the balance of plant including the refueling scheme, NSSS auxiliary and support systems, process support systems, equipment layout, arrangement for all buildings and structures, and an overall plant arrangement. For this process steam plant, the corresponding construction methods were also developed to take

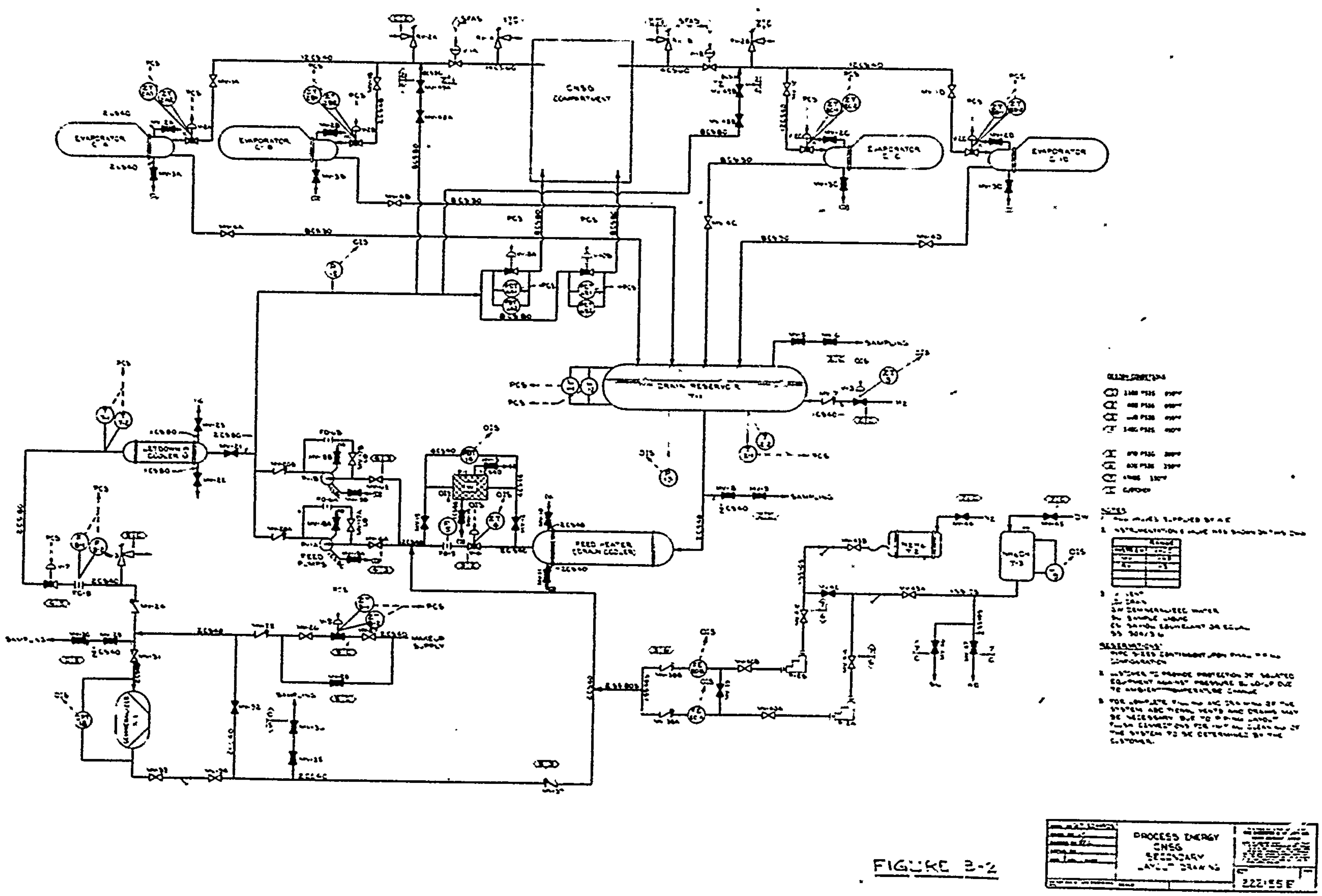
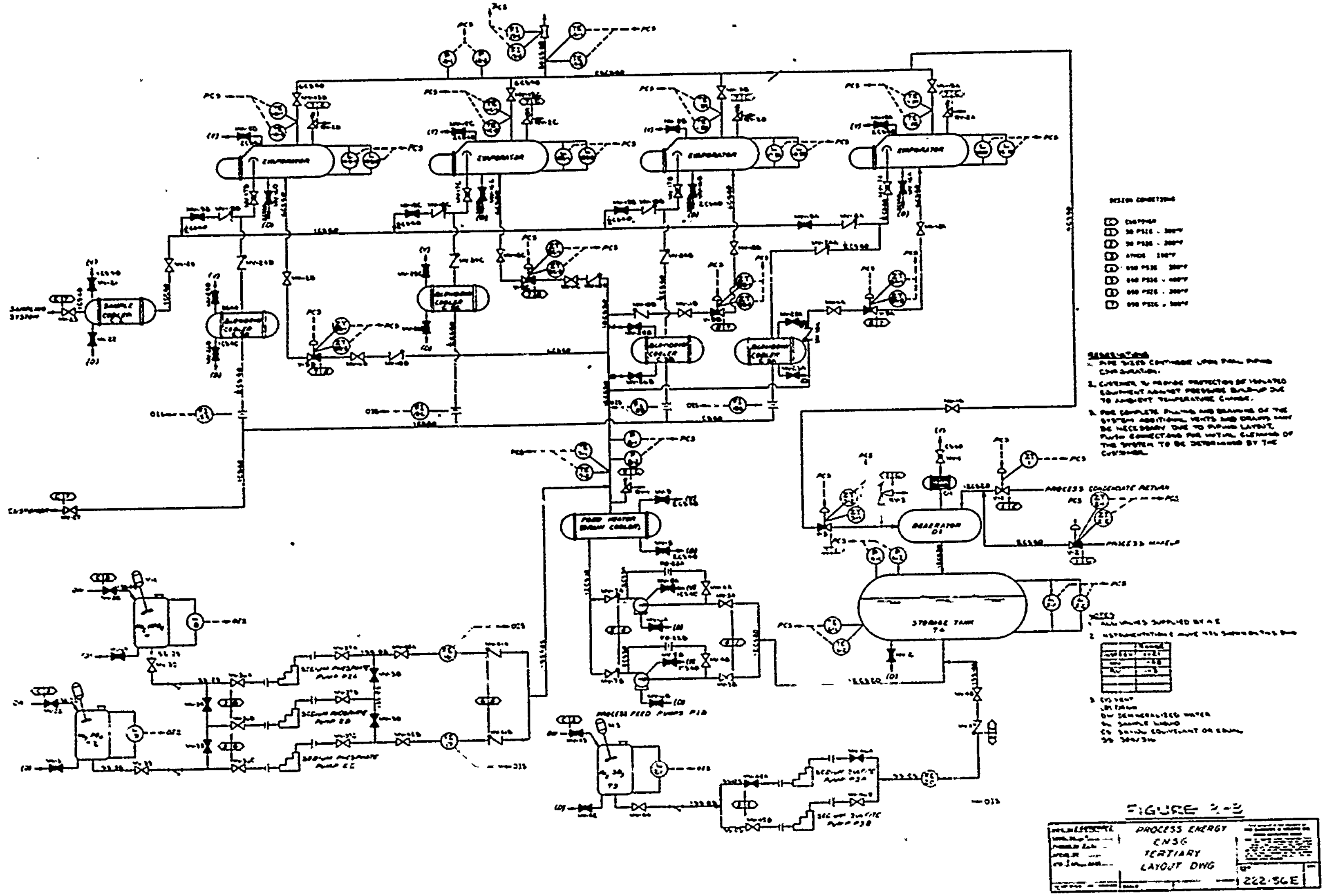

EVAPORATOR C-A
EVAPORATOR C-B
EVAPORATOR C-C
EVAPORATOR C-D
CNSG COMPARTMENT
DRAIN RESERVOIR
FEED HEATER (DRAIN COOLER)
FEED PUMPS
SAMPLING
MAKEUP SUPPLY
PROCESS ENERGY
CNSG
SECONDARY
LAYOUT DRAWING
222155E

FIGURE 3-2



EVAPORATOR
EVAPORATOR
EVAPORATOR
EVAPORATOR
SAMPLING SYSTEM
SAMPLE COOLER
BLOWDOWN COOLER
FEED HEATER (DRAIN COOLER)
DEAERATOR D1
STORAGE TANK T4
PROCESS CONDENSATE RETURN
PROCESS MAKEUP
PROCESS FEED PUMPS P1B
CUSTOMER
PROCESS ENERGY
CNSG
TERTIARY
LAYOUT DWG
222-56E

FIGURE 2-3

advantage of the unique features of the PE-CNSG that accommodate a shorter construction schedule. Capital costs and operating and maintenance costs were then developed for the plant. The results of this effort are contained in Reference 1.

3.2.2 Specific Requirements of the Radford Plant

Whereas in the previous study two separate plants were addressed to produce steam and electricity for the case of RAAP a specific requirement was that a mix of steam and electricity from the same plant would be considered. Furthermore, the previous study was performed for the Middletown site, where no constraints were placed on the PE-CNSG by the steam user. The fact that no condensate return is available at RAAP places definite system requirements which differ from the previous case. Therefore, modifications to the balance of plant as well as modifications to the B&W reboiler design for process steam were required.

Other modifications were also required due to the physical location of the plant and water quality limitations at RAAP. These site characteristics affected the cooling system choice, and required that a water treatment facility be provided. These changes are outlined below and discussed further in subsequent sections.

3.2.2.1 Mix of Steam and Electricity

The recommended mix is developed on certain premises and major factors appertaining to RAAP. A major assumption is that 400 psia saturated steam at the main plant distribution header is acceptable to meet end use requirements. Since most end use requirements need steam at 100 psia or less, and existing

boilers, used primarily for extraction and condensing turbines, produce steam at 450 psia, 750°F, inefficiency results when boiler steam is used for process requirements. It is, therefore, assumed that desuperheaters will be installed. From this basis, an optimum mix was developed by economic evaluation and utilization comparisons. The recommended mix is 570,000 lbs/hr., 450 psi 493°F export steam to the main plant distribution header and 30 MWe of electric generating capacity.

A combination Turbine Generator/Process Steam System was conceptually designed to produce the recommended mix as closely as possible within the limitations of the Turbine Generator/Process Steam equipment. Figure 3-4 shows the heat balance for which the systems were designed.

The availability of suppliers for the turbine generator was investigated, and quotations as well as related design information was obtained. General Electric Company and Worthington Corporation were found to be willing to consider supply of the turbine generator. See references for correspondence and acknowledgements.

Specific details and approach for the selection of the optimum mix warrant careful attention and are presented in Section 4. The recommended mix is used as the design criteria for the PE-CNSG Radford installation plant.

3.2.2.2 Condensate Return

Reboiler design is altered because condensate return is not provided by RAAP. To overcome this design constraint which results in insufficient process steam quantities at required conditions, a modified system was designed using

vendor-supplied data. Southwest Engineering Corporation provided information which was used to include an evaporator and superheater combination that replaces the previously proposed reboiler.

3.2.2.3 Cooling System

Characteristics of the site required investigation into selection of the type of circulating water systems to be employed. Three alternate circulating water systems were considered. Section 3.4, Comparison of Alternate Condenser Circulating Water Systems, gives design information, cost estimates, and engineering rationale from which the selection of a closed system with mechanical draft cooling towers was made.

3.2.2.4 Water Treatment System

Since water cannot be provided at RAAP at a purity level required for the process feedwater that was assumed in the previous study, a water treatment facility to meet these requirements was conceptually designed.

3.2.2.5 Steam Distribution System

The interface with RAAP's existing steam distribution system, a steam supply system which transports process steam from the PE-CNSG to the existing steam distribution system was designed.

3.2.2.6 Electrical Distribution System

To meet RAAP's particular requirements and the mix requirements, the design of the interface of the electrical distribution system was necessary.

3.2.3 Turbine Generator and Process Steam Systems Description

The turbine generator system and the process steam system are once through, parallel systems which convert steam, from the secondary side of the steam

generators, to electric power and process steam, respectively. Feedwater is returned after condensing to the steam generators by common feedwater pumps. Of the 1,254,000 lb/hr of main steam produced by the PE-CNSG, 454,000 lb/hr are directed to the turbine and 800,000 lb/hr are directed to the process steam system.

3.2.3.1 Turbine Generator System

The turbine generator system converts heat into electrical energy by means of a secondary heat transfer loop. Heat from the reactor is transferred to this secondary loop by the steam generator. To ensure flexibility and control under transient conditions, a turbine bypass system has been employed.

Turbine Generator

The turbine generator consists of a 3600 rpm, 29.9 MWe single flow non-reheat steam turbine with a direct coupled, 35 MVA, 3600 rpm, three phase 60 Hertz, air-cooled, synchronous generator. The turbine oil system is used to seal the generator shaft and provide all lubrication.

Of the 454,000 lb/hr steam directed to the turbine generator system, 377,000 lb/hr, 538°F, 700 psia steam passes through the turbine to the condenser with the remaining extraction steam being used for feedwater heating under normal operation conditions.

Condensate System

Steam is exhausted from the turbine to a two pass condenser normally operating at 2 inch Hg vacuum. Vacuum is maintained by two full capacity vacuum pumps. Condensate from the condenser is pumped to the deaerator by two

vertical canned 670 gpm condensate pumps. The deaerator is an open heat exchanger tank which directly mixes the condensate with extraction steam producing 403°F, 650 psia feedwater.

The condensate inventory is maintained with a 40,000 gallon condensate storage tank and transferred to the condensate system via a 20 gpm condensate transfer pump.

To maintain quality of the feedwater, condensate polishers are employed.

Feedwater System

From the deaerator, feedwater is boosted in pressure by the 670 gpm condensate booster pumps. This feedwater joins the feedwater from the process heating steam flow-path and is pumped to the suction of the steam generators by the motor driven 2,500 gpm main feedwater pumps. Feedwater enters the steam generators at 850 psia and 403°F.

Circulating Water System

The circulating water system removes heat from the condenser and the secondary component cooling water heat exchangers. Heat is rejected to the atmosphere by a mechanical draft cooling tower. Cooled water is collected in the cooling tower basin, pumped through the condenser and back to the cooling tower by two vertical, wet pit, 18,134 gpm, circulating water pumps.

3.2.3.2 Process Steam System

The criticality of specific requirements of the recommended mix and the implications of turbine limitations on the design of the process steam system equipment necessitated contact with vendors for more detailed design information. Southwest Engineering Corporation and Chicago Heater provided significant

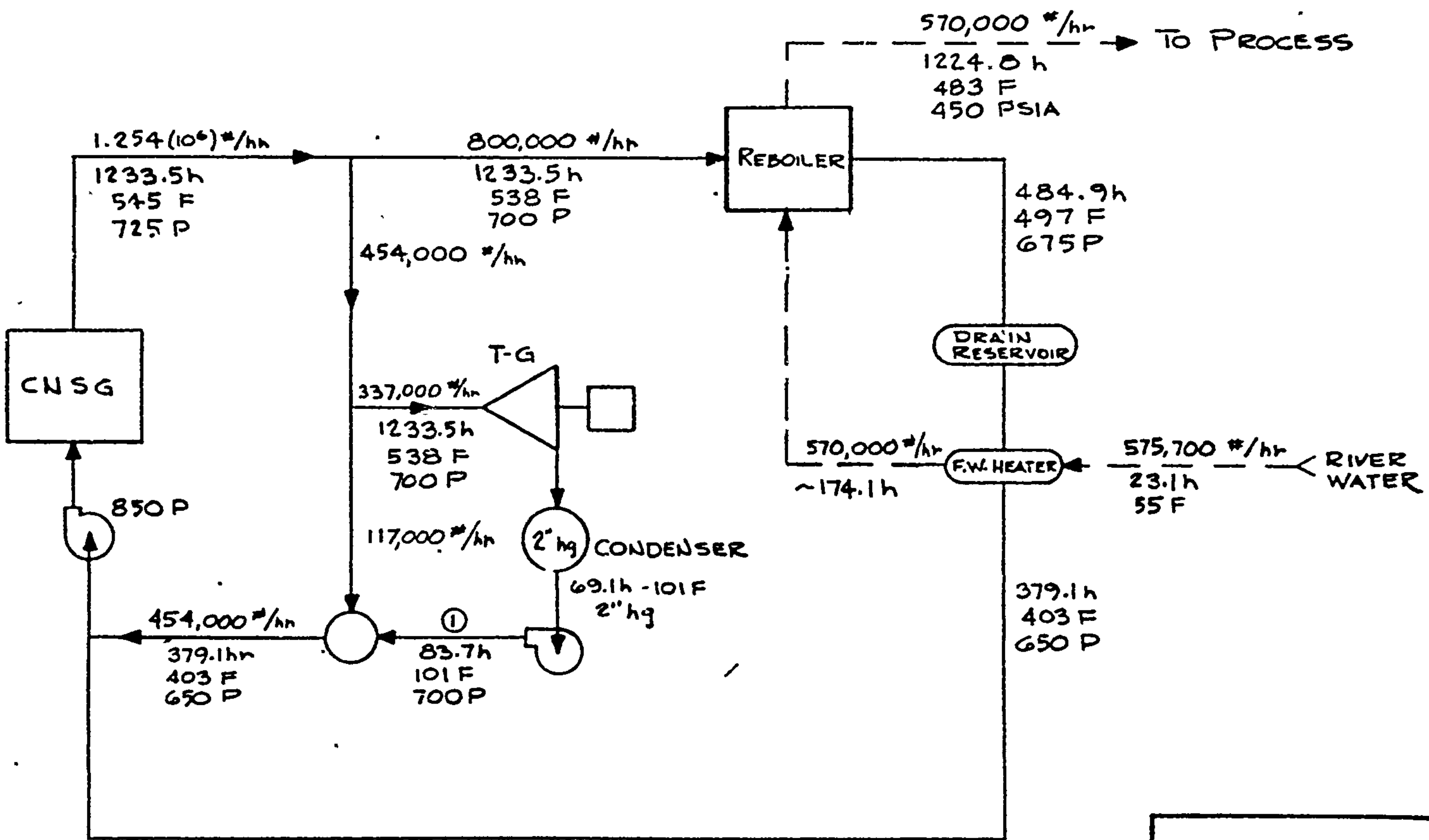
information and costs to address these concerns. It was found that single stage heating of the process flow as in the ERDA study was unacceptable for the temperature requirements of the Radford Arsenal. A two stage system consisting of an evaporator and superheater was found necessary for the conditions of the recommended mix.

The process steam system transfers heat from the reactor to the process steam system by means of a secondary heat transfer loop. Heat from the reactor is transferred to the secondary loop by the steam generators located within the PE-CNSG and given off to the process steam system by evaporators and superheaters.

Secondary System

Three shell and tube evaporators and superheaters arranged in parallel take 800,000 lb/hr steam from the secondary side of the steam generators to heat process feedwater for process steam requirements. The system is designed to produce 26^{O}F superheated process steam. The secondary steam enters the superheater and evaporator train at 700 psia 538^{O}F and exits to a drain reservoir at 675 psia, 497^{O}F, where the fluid level is monitored and controlled. Flow continues to the tube side of the feedwater heater where heat is given off to preheat the process (or tertiary) feedwater. From the feedwater heater, the flow at 650 psia, 403^{O}F continues to the main feedwater pumps discussed in Section 3.2.11 where feedwater from turbine generator system joins before entering the inlet side of the steam generators.

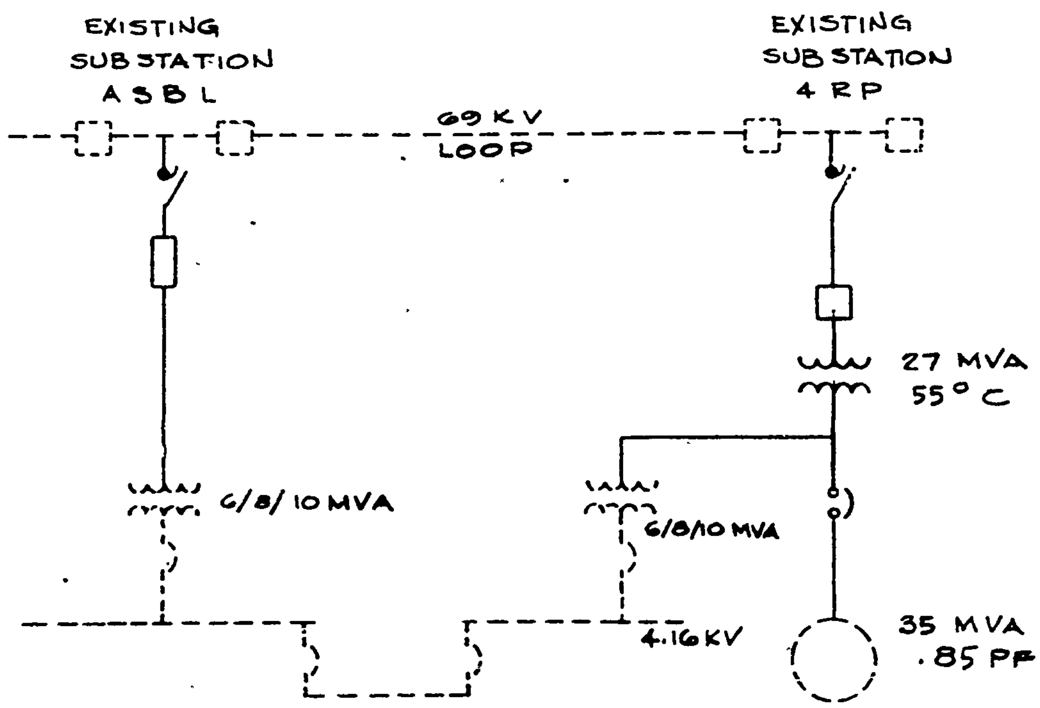
A secondary chemical addition system and sampling system, consisting of letdown coolers, condensate filter, chemical addition drums and pumps, and sampling points, is employed to maintain proper water quality.



PROCESS DIAGRAM
1-E-CNSG - ELECTRIC STEAM GENERATION PLANT

United Engineers

FIGURE 3-4



KEY ONE-LINE
DIAGRAM

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FIGURE 3-5

3.2.3.3 Secondary Auxiliary Systems

Closed Cooling Water System

A separate closed cooling water system is provided to remove heat from the secondary plant components of both the turbine generator system and the process steam system. It includes three 1,000 gpm pumps, three shell and tube heat exchangers, and a 200 cu. ft. surge tank.

River Water System

The river water system provides water for makeup to all requiring systems. It consists of an intake structure on which trash racks, traveling screens, screen wash pumps, de-icing pumps and river water intake pumps are mounted. Chlorination is introduced at the traveling screens to prevent algae buildup.

Water Treatment System

The water treatment system employs gravity filters, a clarifier, and vacuum filters to provide makeup water requirements to all systems requiring treated water. A detailed description of the water treatment system is given in Appendix 4.

Cation and Anion unit demineralizers are used for the necessary demineralized water requirements.

Diesel Generators

Two 1500 kW diesel generators complete with controls, fuel oil storage and transfer facilities are provided for emergency back up power.

3.3 Plant Layout

The main features of the site which affect the design and cost of the Radford PE-CNSG plant are a closed cooling water (circulating water) system which

rejects heat from the condensers and heat exchangers to the atmosphere by means of mechanical draft cooling towers, the subsoil conditions of soft shale and hard shale requiring excavation, and the necessity of constructing an access road to the site.

The plant layout is shown in Drawing 6390.002-D-001. The plant consists of a reactor service building which contains the PE-CNSG, its containment, and all supporting nuclear auxiliary systems; a control building, a diesel generator building with an adjacent turbine service building; an administration building; an intake structure; an ultimate heat sink cooling tower, a condenser cooling tower; and, miscellaneous buildings such as gatehouses, parking areas, etc.

In the main building area, the nuclear, Seismic Category 1 structures are separated from the turbine/process buildings by a piping tunnel which facilitates simultaneous construction and access. The cooling tower area is located south of the main plant structures on a higher nominal elevation.

The reactor containment vessel is located inside the reactor service building. Normal personnel access to the containment is provided by an air lock at building elevation 46'-0". Refueling access is provided at the top of the containment by a removable lid. Access to the area under the reactor vessel is provided by an access tunnel and bolted containment closure.

3.3.1 Reactor Service Building

The reactor service building is a tornado-proof, Seismic Category I structure founded on a mat foundation with reinforced concrete exterior walls, interior walls, and roof. The heavy supports required for the refueling canal are reinforced concrete columns. The floors are reinforced concrete on metal

floor decking supported by structural steel floor framing. The layout of systems within the reactor service building is based on past experience with large nuclear power plants. The location of major equipment is shown on drawings 6390.002-D002 to 008. Shielded cubicles are provided for potentially radioactive handling equipment. The building layout is so designed as to minimize piping runs and interferences, and to shorten construction schedules.

The refueling system employs a conventional method of wet refueling, where all operations are performed under water. Underwater transfer of spent fuel assemblies provides an effective, transparent radiation shield as well as a reliable cooling medium for removal of decay heat. The use or borated water provides an added safety margin that will ensure subcritical conditions during refueling.

The reactor service bridge crane is rated at 250 tons to handle the 180 ton weight of the reactor vessel closure head, including its service structure. reactor coolant pumps, and control rod drive mechanisms. The main hook is rotatable and has a sister hook for redundancy. Rail stops permit laydown of the containment lid and restrict the main hook from traveling over spent fuel. The fuel and cask handling bridge crane is rated at 125 tons to handle the spent fuel shipping cask. Rail stops permit access to the centerline of the cask loading and cask maintenance pits, and restrict the main hook from traveling over the new fuel storage vault. Two monorails attached to the crane girders handle new fuel assemblies. These hoists permit five ton coverage outside the main hook limits. This crane lowers a filled shipping cask through hatches to a truck below.

3.3.2 Control Building

The control building is a tornado proof, Seismic Category I structure founded on a mat foundation with reinforced concrete exterior walls and roof. The floors are reinforced concrete on metal floor decking supported by structural steel framing. Space is provided for control boards, computer equipment, relay racks, etc.

3.3.3 Diesel Generator Building and Diesel Fuel Oil Storage Building

The diesel generator building is a seismic Category I structure. The diesel generators are housed in separate compartments for independency. The fuel oil storage building is a concrete reinforced vault with the roof at grade elevation. The fuel oil storage tanks are also housed in separate compartments. The design is such that an oil spill or fire can be easily contained.

3.3.4 Ultimate Heat Sink Cooling Tower

The ultimate heat sink cooling tower is also a nuclear, Seismic Category I structure. Cooling is supplied to the nuclear component cooling water system by means of a two cell mechanical draft cooling tower.

3.3.5 Intake Structure

The intake structure is another Seismic Category I structure which supplies makeup water for all plant needs. The intake structure is designed for a water velocity of 0.5 fps through the screens for fish escape.

3.3.6 Turbine/Process Building

The turbine/process building is a metal sided, structural steel framed building which rests on reinforced concrete footings. A reinforced concrete grade slab and reinforced concrete on metal decking comprises the interior

floors. The built up roofing is supported on structural steel trusses. The turbine generator is supported on a reinforced concrete pedestal foundation and is situated in a position that excludes all Seismic Category buildings from a 25^{o} angle measured from the perpendicular of the shaft taken at the nearest turbine blade. The process reboilers are supported on reinforced concrete foundations.

3.3.7 Turbine Service Building

The turbine service building is a metal sided, structural steel framed building which houses the auxiliary boilers, machine, and tool shops.

3.3.8 Administration Building

The administration building is also a metal sided, structural steel framed building with built up roofing and supported on reinforced concrete footings

3.3.9 Condenser Cooling Tower

The condenser cooling tower is a mechanical draft tower which provides cooling for the circulating water system.

3.3.10 Miscellaneous

Very large equipment such as large tanks (demineralized water storage tank, condensate storage tank) and plant transformers are located outside the main buildings. Minimal weather protection is provided for the outside equipment.

The entire facility is enclosed by a security fence. The relatively small area of the plant with its single access provides a favorable condition for plant security.

Two independent off-site power sources, the diesel generator, and the DC systems, ensure a reliable power supply for the plant's critical systems. Figure 3-5 shows the plant key one line diagram. See drawings 6390.002-D-001 to D-008 for building arrangements.

3.4 Comparison of Alternate Condenser Circulating Water Systems

A preliminary analysis was performed to compare the costs of three alternate circulating water systems:

- o once-through cooling system
- o mechanical draft cooling tower system
- o natural draft cooling tower system

Due to the large difference in elevation between river level and turbine process building grade, which requires that the once-through circulating water system employ high head circulating water pumps, an investigation was made into incorporating a recovery turbine in the discharge of the cooling system.

The systems were designed using the following engineering data:

Design Parameter	Once-through Cooling	Mechanical Draft Cooling	Natural Draft Cooling
Condenser heat-rejection rate	290×10^6 Btu/hr	290×10^6 Btu/hr	290×10^6 Btu/hr
Turbine back pressure	1.5 in. HgA	2.0 in. HgA	2.0 in. HgA
Inlet water temp.	70°F	80°F	80°F
Wet bulb temp.	--	72°F	72°F

The following cost comparison was based on information supplied by vendors and current cost data.

SUMMARY OF COST ESTIMATES

Direct Cost	Once-Through Cooling System	Mechanical Draft Cooling System	Natural Draft Cooling System
Condenser	$518,000	$488,000	$488,000
Circulating Water Piping	581,000	156.000	156,000
Circulating Water Pumps and Motors	191,000	162,000	162,000
Intake Screens and Intake and Discharge Structures	231,500	13,500	13,500
Cooling Tower	--	614,000	3,600,000
Makeup and Blowdown Facility	--	147,600	147,600
Recovery Turbine	96,000	--	--
Total Direct	$1,521,500 w/o Recovery Turbine	$1,581,000	$4,567,100
Capital Cost (excluding pumphouse)	$1,617,500 w Recovery Turbine		
Aux. Power Requirements	1800 kW w/o Recovery Turbine; 720 kW w Recovery Turbine	1000 kW	660 kW

The results of the analysis indicate that direct capital costs and auxiliary power requirements for the mechanical draft cooling tower system are comparable to the once-through cooling system. After considering factors such as expense, effort, and time delay involved in assessing the environmental

impact of the once-through cooling system in anticipation of meeting governmental regulations, it is judged that the mechanical draft cooling system is a more viable alternative.

3.5 Steam Distribution System

Overriding economic considerations preclude that the interface of the PE-CNSG steam generating plant with the steam distribution system be accomplished by maximum utilization of the existing steam distribution system with a minimum of new steam supply piping. The steam distribution interface is attained by the installation of two new steam supply lines. These lines consist of a main supply line from the PE-CNSG steam generating plant to the existing distribution header at Boiler House No. 1, and a branch line from the existing distribution header at Boiler House No. 1 to the existing horseshoe header at Boiler House No. 2.

The installation requires several thousand feet of piping which crosses creeks, roads, railroads, general plant areas, and the New River. Construction, maintenance, and topographic limitations prevent a straight line layout of the steam supply lines. The general routing of the new supply lines is shown on Drawing 6390.002-S-001.

Optimum pipe sizes have been selected and pipe wall thicknesses have been established to satisfy the requirements of the Power Piping Code ANSI B31.1-1973 and succeeding addenda. General engineering data of the two steam supply lines is given on the following page.

	Main Line from PE-CNSG to Boiler House No. 1	Branch Line from Boiler House No. 1 to Boiler House No. 2
Flow, lb/hr	570,000	150,000
Pressure, psia at inlet required	450 400	400 200
Temperature, ^{o}F	493	472
Pipe Material	CS	CS
Pipe diameter, inches	24	12
Pipe wall thickness, inches	0.5	0.25
Pipe Schedule	XS	20

The new steam supply lines are designed to be installed above ground with concrete supports, except at river, road, or railroad crossings. The 24 inch diameter main supply line is designed for fixed type supports spaced at 300 feet with sliding type supports spaced at 50 feet. The 12 inch diameter branch line is designed for fixed type supports spaced approximately 210 feet apart with sliding type supports every 35 feet. See Figure 3-6 for support details.

A double wrapping of mineral wool insulation with corrugated aluminum jacketing is employed. Expansion loops are provided for thermal expansion and contraction of the lines. Condensate is removed by drains at appropriate intervals employing steam traps and standard hotwells embedded in rock or gravel.

For the portions of the steam supply lines which are installed underground, "Ric-Wil" prefabricated insulated piping is used in conventional trench type installations. "Ric-Wil" prefabricated manholes are used at underground entrance and exit points. See Figure 3-7.

The routing of the steam supply lines requires clearing and grading of several hundred feet of wooded areas, underground crossings of creeks, roads, and railroads, and an underground trench-laid crossing of the New River. See Figure 3-8 for typical cross-section.

3.6 Special Engineering Safeguards

Due to the latest inherent potential hazard of munitions explosions in the plant site vicinity, an investigation into special safeguards to ensure nuclear systems integrity is necessary. Section 2 has presented a postulated, "worst-case", explosion which occurs east of the nuclear plant site involving a truck transporting TNT. The postulated explosion shock wave over-pressure was determined to be 10 psi as stipulated in Section 2 and is considered to be a worst case. This criteria was used for a basic static pressure analysis. Seismic Category I buildings have been designed for tornado missile impingement, therefore, explosion missile impingement will require no additional design considerations.

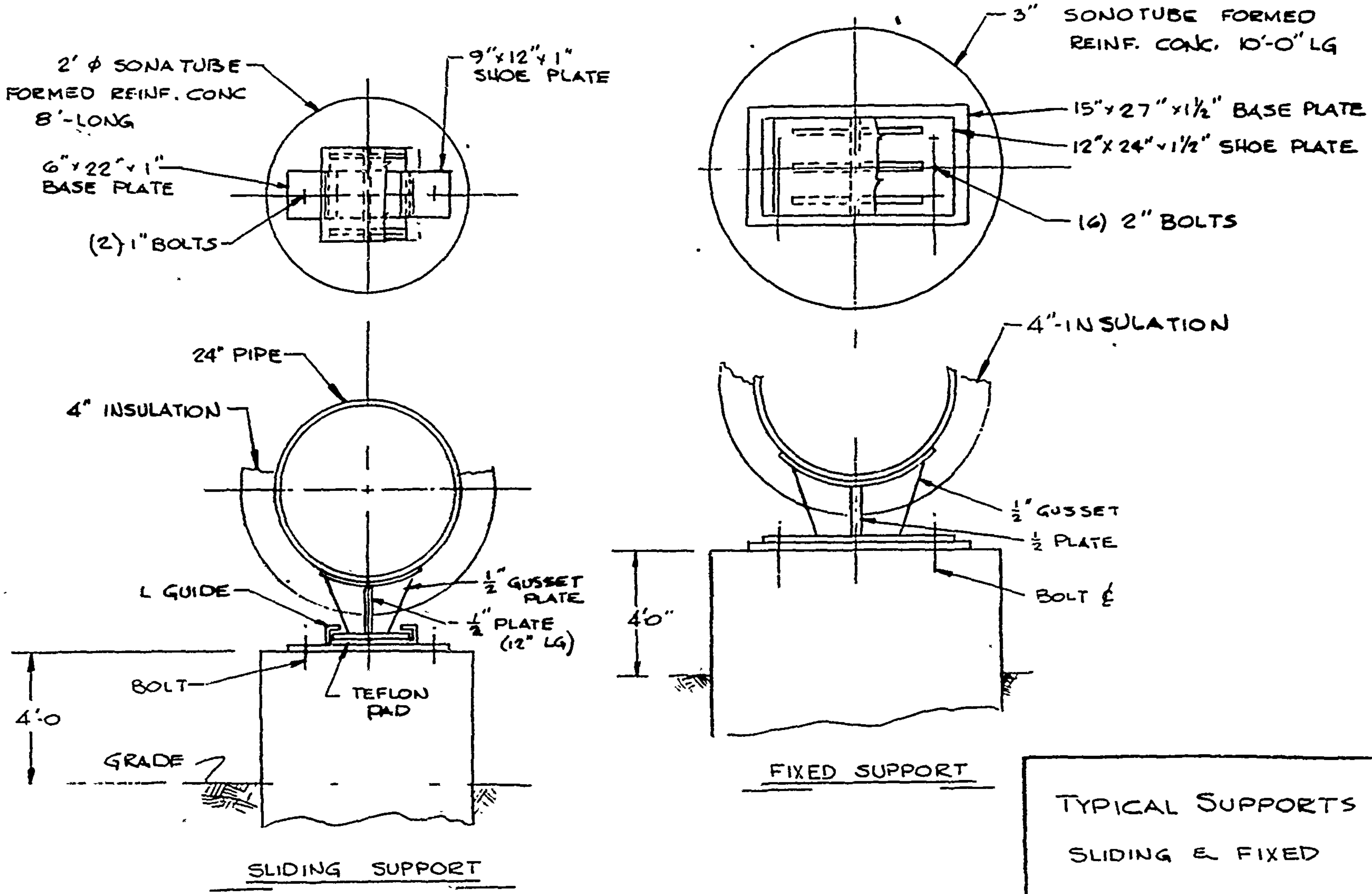
A basis static pressure analysis was performed for all Seismic Category I buildings which would be exposed to a shock wave from the postulated explosion location. The structures considered are the Reactor Service Building, Diesel Generator Building, Diesel Fuel Oil Storage Building, and Ultimate Heat Sink Cooling Tower. It was found that certain structures would require "hardening" to withstand the shock wave overpressure. The hardening would consist of additional concrete and reinforcing steel for exterior walls.

The additional concrete and reinforcing steel required for the structures was estimated and the additional costs that would be incurred were assigned. The following table presents these quantities and corresponding costs.

Additional Quantities Required for Hardening		Estimated Cost
Reactor Service Building		
Concrete	1,280 cy	
Rebar	900 tons	
Diesel Generator Building		
Concrete	none	
Rebar	56 tons	$ 826,000
Diesel Fuel Oil Storage Building		
Concrete	none	
Rebar	none	
Ultimate Heat Sink Cooling Tower		
Allowance		250,000
Subtotal		$1,076,000
20% Contingency		224,000
TOTAL ADDITIONAL DIRECT COST		$1,300,000

Because the Diesel Fuel Oil Storage Building is a bunker type structure with grade at roof elevation, no additional concrete and reinforcing steel is required. The Control Building is shielded from the postulated explosion location by other structures.

The investigation that was performed is basic and preliminary in nature, but it does reflect order or magnitude results. In particular, the shielding of the control building is mentioned only in a qualitative fashion since no calculations were performed to take this into account. Nor have any detailed calculations of shock-wave behavior been carried out. An in-depth, dynamic analysis would be required for more exact conclusions. However, it should be recognized that the 10 psi predicted from the explosion is not a detailed calculation either; and, is conservative. Should detailed analysis be contemplated in the future, it is clear that the 10 PSI prediction would be the first item to be considered. However, in any case, it appears on the basis of these results, that a major impact on the overall cost of the plant does not result from this added protection; and certainly not enough to alter the conclusions of the economic evaluation of Section 4.

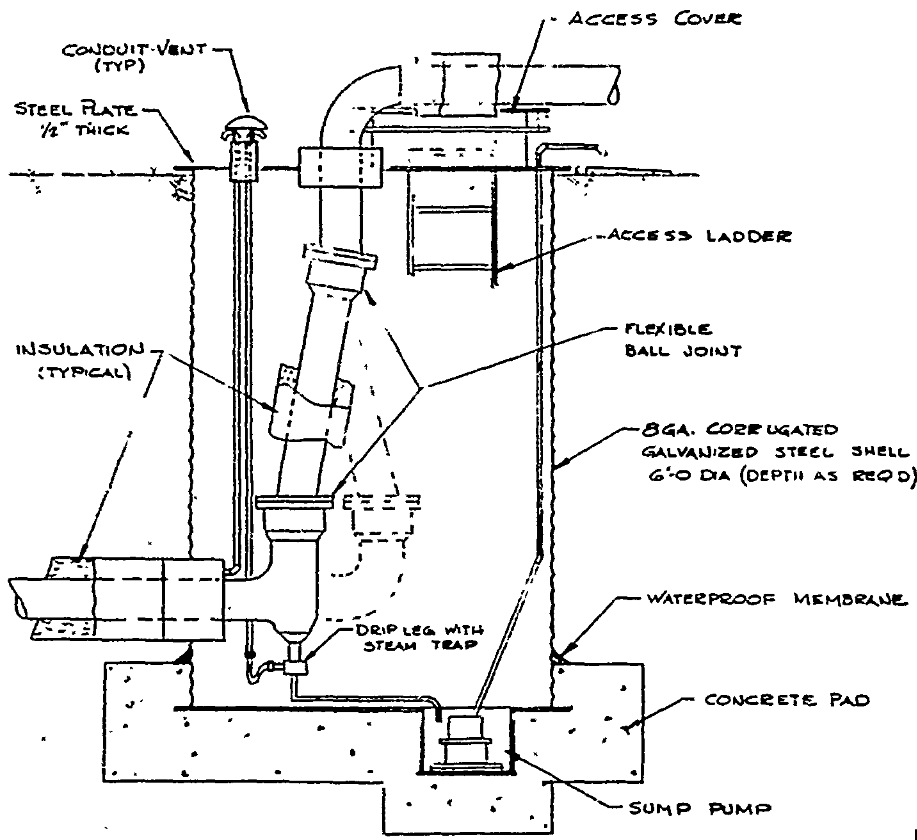


TYPICAL SUPPORTS

SLIDING & FIXED

united engineers & constructors inc

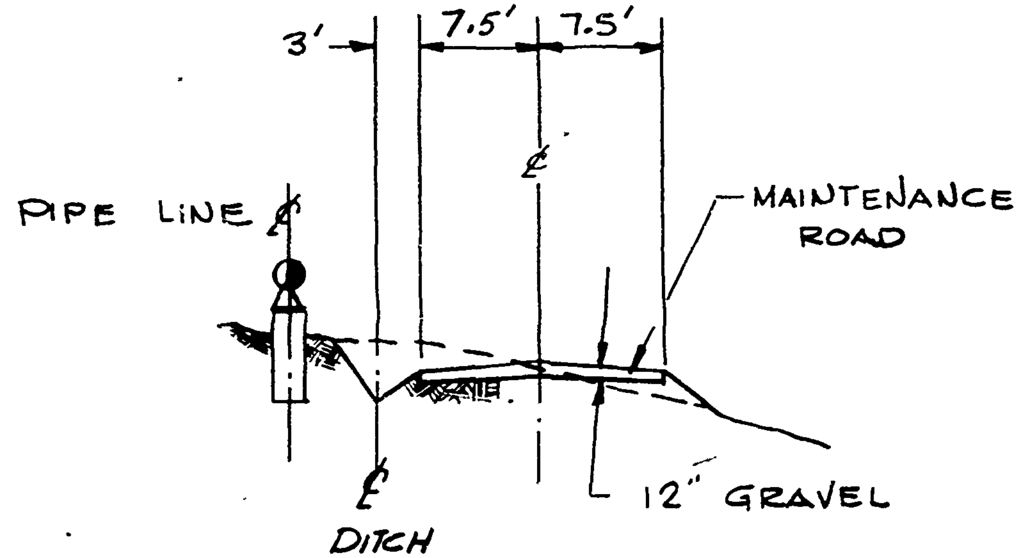
FIGURE 3-6



TYPICAL
EXPANSION JOINT
MANHOLE

united engineers

FIGURE 3-7



MAINTENANCE ROAD
TYPICAL CROSS SECTION

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FIGURE 3-8

3.7 Equipment List

The following Equipment List describes those components which form part of the B&W PE-CNSG and related Balance of Plant equipment. Each of the components is briefly described in terms of design pressures, temperature flow, capacities, materials, etc. sufficiently to correlate these with the Cost Estimate of Section 3.8.

As a convenience for cross-referencing between the Cost Estimate and the Equipment List, the account number has been added at the left-hand column of the Equipment List. These account numbers are intended to correlate with equipment identified in the Cost Estimate.

This equipment list is based on the equipment list generated for the ERDA study by B&W previously discussed in Section 3.2.1, Basis for Present Plant Design. It reflects, however, the changes made necessary to modify the design of that study so that it satisfies the requirements of RAAP, as described in Section 3.2.2, Specific Requirements of the Radford Plant.

EQUIPMENT LIST

Account No.		Description
212.22	HEATING & VENTILATION SYSTEMS (Containment Structure)	
	Containment Dry Well Cooling System	Containment dry well cooling system moisture separator and cooling units complete with cooling water coils, demisters, HEPA filters, centrifugal fans with motors, carbon filters, automatic controls, and ductwork with control rod drive cooling subsystem.
	Reactor Compartment Ventailation System	Air tempering units complete with fan, motor, steam coils, filters, controls, and distribution ductwork.
213.22	HEATING & VENTILATION SYSTEMS (Process/Turbine Building)	
	Heating	Ten (10) steam unit heaters each complete with motor and controls.
	Ventilation	Eight (8) roof ventilators complete with motors, dampers, and controls.
	Fire Protection	Eight (8) hose stations complete with hose reels or cabinets, nozzles, and 100 feet of 1½ inch CRL hose.
215.22	HEATING & VENTILATION SYSTEMS (Reactor Service Building)	
	Heating	Ten (10) steam unit heaters each rated at 40,000 Btu/hr.
	Ventilation	One air tempering unit complete with steam coils, filters, controls and distribution ductwork.
		One set of exhaust fans complete with dampers, HEPA filters, controls, and ductwork.
218A.22	HEATING & VENTILATION SYSTEMS (Control Building)	
	Heating	One set of sill-line heaters.
	Ventilation	Two (2) exhaust fans and motors complete with make up air louvers and controls.

Account No.		Description
	Air Conditioning	Air conditioning equipment complete with ductwork, HEPA and carbon filters, and booster fans for emergency use, and remote controls. Two (2) exhaust fans, same as above, with motors.
218B.22	HEATING & VENTILATION (Diesel Generator Building)	
	Heating	One set of electric unit heaters complete with controls.
	Ventilation	Six (6) wall exhaust (3 standby) fans provided with motor operated make up air louvers to suit exhaust requirements.
218C.22	HEATING, VENTILATING, AND AIR CONDITIONING (Administration Building)	
		Air conditioning including supply and return ductwork, controls, necessary exhaust systems, electric baseboard heat, etc.
	Fire Protection	Ten (10) hose stations complete with hose reels or cabinets, nozzles, and 50 feet of 1½ inch CRL hose.
218D.22	HEATING & VENTILATION (Turbine Service Building)	
		Necessary exhaust systems, electric baseboard heat, etc.
	Fire Protection	Hose stations complete with hose reels or cabinets, nozzles, and 50 feet of 1½ inch CRL hose.
218E.22	HEATING & VENTILATION (Make Up Water Pumphouse)	
	Heating	One set unit heaters complete with controls.
	Ventilation	Three (3) exhaust fans and motors, wall mounted, complete with dampers, make up air louvers, and controls.

Account No.		Description
218F.22	HEATING & VENTILATION (Circulating Water Pumphouse)	
	Heating	One set unit heaters complete with controls.
	Ventilation	Three (3) exhaust fans and motors complete with dampers, makeup air louvers, and controls.
218G.22	HEATING & VENTILATION (Service Water Pumphouse)	
	Heating	One set of unit heaters complete with controls.
	Ventilation	Two sets (one backup) of exhaust fans and motors complete with ductwork, dampers, automatic makeup air louvers, and controls.
221.12	Reactor	314 MWt Pressurized water reactor. Light water is used as moderator and coolant. Design pressure 2500 psig, design temperature 650°F. Carbon steel vessel of 157 inches inside diameter and 34 feet-8 inches in length. Fuel used is enriched uranium dioxide pellets.
222.111	Reactor Coolant Pumps	Four vertically mounted, wet-motor, single stage, mixed flow pumps. Capacity of 18,950 gpm at 106 feet of head.
222.131	Steam Generators	Twelve modular once-through steam generators each with 993 half inch inconel tubes. Total steam flow of 1,250,000 lb/hr at 700 psia and 538°F (35°F superheat). Feedwater temperature of 400°F.
222.141	Pressurizer	One separate pressurizer connected to reactor vessel by surge line.
222.145	Pressurizer Spray Pumps	Two pressurizer spray pumps designed to accommodate the pressurizer.
223.111	Decay Heat Removal Pumps	Two (2) single-stage, centrifugal decay heat removal pumps, capacity: 500 gpm at 475 feet heat, design pressure: 675 psig, design temperature: 350°F.

Account No.		Description
223.121	Decay Heat Removal Heat Exchangers	Two (2) shell and tube heat exchangers with carbon steel shell and stainless steel tubes. Tube side design pressure of 675 psig, design temperature 350°F. Shell side design pressure of 225 psig, design temperature 200°F.
223.311	Emergency Decay Heat Removal Pumps	Two (2) 400 gpm, 200 HP motor emergency decay heat removal pumps.
224.111	Waste Holdup Tanks	Four (4) 800 cu. ft. austenitic SS waste hold up tanks, 8 feet dia. by 16 feet high. Design pressure-atmospheric, design temperature 150°F.
224.112	Spent Resin Storage Tank	One (1) 500 cu. ft. austenitic SS spent resin storage tank. Design pressure-Atm., design temperature 150°F.
224.113	Reactor Coolant Drain Tank	One (1) horizontal austenitic SS reactor coolant drain tank. Design pressure-15 psig, design temperature-200°F, capacity - 700 cu. ft.
224.114	Chemical Drain Tank	One (1) 400 cu. ft. austenitic SS chemical drain tank. Design pressure-Atm, design temp.-150°F.
224.115	Hot Shower & Laundry Drain Tank	One (1) 400 cu. ft. austenitic SS hot shower and laundry drain tank. Design pressure - Atm., design temperature-150°F.
224.116	Waste Sump Tanks	Two (2) 300 cu. ft. austenitic SS waste sump tanks. Design pressure-Atm., design temperature 150°F.
224.117	Regenerant Caustic Mix Tank	One (1) 100 cu. ft. austenitic SS regenerant caustic mix tank. Design pressure-Atm., design temp.-150°F.
224.118	Waste Evaporator Feed Tank	One (1) 600 cu. ft. austenitic SS waste evaporator feed tank. Design pressure-Atm., design temp.-150°F.
224.119	Waste Evaporator Test Tanks	Two (2) 400 cu. ft. austenitic SS waste evaporator distillate test tanks. Design pressure-Atm., design temperature-200°F.

Account No.		Description
224.120	Waste Evaporator Storage Tank	One (1) 600 cu. ft. austenitic SS waste evaporator distillate storage tank. Design pressure-Atm., design temp.-200°F.
224.121	Waste Evaporator Concentrate Storage Tank	One (1) 500 cu. ft. austenitic SS waste evap. concentrate storage tank. Design pressure-Atm., design temp.-150°F.
224.131	Waste Transfer Pumps	Four 100 gpm at 200 ft. head waste transfer pumps. Design pressure 150 psig, design temp.-200°F.
224.132	Resin Transfer Pump	One 50 gpm at 139 ft. head resin transfer pump. Design pressure 150 psig, design temp.-200°F.
224.133	Spent Resin Sluice Pump	One 100 gpm at 231 ft. head spent resin sluice pump. Design pressure 150 psig, design temp.-200°F.
224.134	Reactor Coolant Drain Tank Pumps	Two 50 gpm at 200 ft. head reactor coolant drain tank pumps. Design pressure 150 psig, design temp.-200°F.
224.135	Chemical Drain Tank Pump	One 50 gpm at 200 ft. head chemical drain tank pump. Design pressure 150 psig, design temp.-200°F.
224.136	Laundry & Hot Shower Drain Tank Pump	One 50 gpm at 200 ft. head laundry & hot shower drain tank pump. Design pressure 150 psig, design temp.-200°F.
224.137	Waste Sump Tank Pumps	Four 50 gpm at 200 ft. head waste sump tank pumps. Design pressure 150 psig, design temp.-200°F.
224.138	Regen. Caustic Pump	One 20 gpm at 231 ft. head regen. caustic pump. Design pressure 150 psig, design temp.-200°F.
224.139	Waste Evaporator Feed Pump	One 50 gpm at 50 ft. head waste evaporator feed pump. Design pressure 150 psig, design temp.-200°F.
224.140	Waste Evaporator Distillate Transfer Pumps	Two 100 gpm at 150 ft. head waste evaporator distillate transfer pumps. Design pressure 150 psig, design temp.-200°F.

Account No.		Description
224.141	Waste Evaporator Concentrate Transfer Pump	One 50 gpm at 150 ft. head waste evaporator concentrate transfer pump. Design pressure 150 psig, design temp.-200°F.
224.151	Waste Evaporator Distillate Demineralizer	One SS, 40 cu. ft., mixed bed waste evaporator distillate demineralizer. Design pressure 150 psig, design temp.-200°F.
224.153	Evaporator Distillate	One SS, 40 cft distillate demineralizer. Design pressure 150 psig, design temp.-200°F.
224.161	Liquid Waste Filter	One SS, 100 g/25 M.A. liquid waste filter. Design pressure 150 psig, design temp.-200°F.
224.162	Waste Evaporator Feed	Two SS 100 g/25 M.A. waste evap. feed filter design pressure 150 psig, design temp.-200°F.
224.163	Demineralize Distillate Filter	One SS 100 gpm/25 M.A. demineralize distillate filter. Design pressure 150 psig, design temp.-200°F.
224.171	Reactor Coolant Drain Tank Cooler	One 1.0E6 Btu/hr SS RC Coolant Drain tank cooler. Design pressure 150 psig, design temp.-300°F.
224.181	Evaporator Waste Unit	One 25 gpm evaporator waste unit. Design pressure 60 psig, design temp.-308°F.
224.191	Containment Sump Tank	One SS 270 cft containment sump tank. Design pressure-Atm., design temp.-200°F.
224.192	Containment Sump Pumps	Two 60 gpm at 150 ft. head sump pumps. Design pressure 150 psig, design temp.-200°F.
224.21	Gas Decay Tanks	Six SS 300 cft gas decay tanks. Design pressure 150 psig, design temp.-200°F.
224.22	Waste Gas Compressors	Four 30 cfm/120 psig waste gas compressors.

Account No.		Description
224.23	Gas Analyzer	One model 15 gas analyzer.
224.24	Gas Surge Tank	One 150 psig, 200°F gas surge tank.
224.25	H_2O_2 Recombiners.	Two 40 scfm, 140°F Recombiners (rate = 1.4 scfm)
224.281	Waste Gas Filter	One 200 cfm, SS waste gas filter.
224.35	Solid Waste Compactor	One baler with dust shroud and absolute filter for solid wastes.
224.37	Solid Waste Solidifying Agent Injection Unit	One injection pump and agent injection unit.
224.411	Mixing & Neutralization Tank	One SS 800 cft mixing and neutralization tank. Design pres.-Atm., design temp.-200°F.
224.412	Regen. Solution Storage Tanks	Two SS 600 cft regen. solution storage tank. Design pres.-Atm., design temp.-150°F.
224.413	Evaporator Feed Tank	One SS 800 cft evaporator feed tank. Design pres.-Atm., design temp.-150°F.
224.414	Evaporator Distillate Tanks	Two SS 400 cft evaporator distillate tanks. Design pressure-Atm., design temp.-150°F.
224.415	Evaporator Concentrate Storage Tank	One SS 300 cft evaporator concentrate storage tank. Design pressure-Atm., design temp.-150°F.
224.422	Evaporator Feed Pump	One 50 gpm at 50 ft. evaporator feed pump design pressure 150 psig, design temp.-200°F.
224.423	Evaporator Distillate Transfer Pumps	Two 100 gpm at 150 ft. head evaporator distillate transfer pumps. Design pressure 150 psig, design temp.-200°F.
224.424	Evaporator Concentrate Transfer Pump	One 50 gpm at 150 ft. head evaporator concentrate transfer pump. Design pressure 150 psig, design temp.-200°F.

Account No.		Description
224.425	Mix Tank Transfer Pump	One 200 gpm at 231 ft. head mix tank transfer pump. Design pressure 150 psig, design temp.-200°F.
224.426	Mixing Pump	One 200 gpm at 231 ft. head mixing pump. Design pressure 150 psig, design temp.-200°F.
224.431	Evaporator Distillate Demineralizer	One SS 100 gpm/40 cft distillate demin. Design Pressure 150 psig, design temp.-200°F.
224.441	Regen. Solution Storage Pumps	Two 200 gpm at 231 ft. head regen. solution storage pumps. Design pressure 150 psig, design temp.-200°F.
224.451	Feed Filters	Two 100 gpm/25 M.A. SS Feed filters.
224.452	Distillater Demineralizer Filter	One 100 gpm/25 M.A. SS Demineralizer Filter.
224.511	Secondary Waste Evaporator Unit	One 25 gpm secondary waste evaporator unit.
224.611	Drumming Station Crane	One 5 ton overhead traveling crane for drum handling. 14 foot lift, hoist speed 10 fpm, bridge speed 37.5 fpm, trolley speed 20 fpm.
225.13	Fuel Elevator	One submerging type nuclear fuel elevator.
225.2	Remote Viewing Equipment	Television, optical system, and special lighting for remote viewing equipment.
225.41	New Fuel Storage Racks	One set of new fuel storage racks.
225.42	Spent Fuel Storage Racks	One set of spent fuel storage racks.
225.4311	Spent Fuel Pit Cooling Pumps	Two horizontal, centrifugal SS spent fuel pit cooling pumps 700 gpm at 50 ft. head, design pressure 150 psig, design temp.-200°F.
225.4312	Spent Fuel Pit Skimmer Pump	One horizontal, centrifugal SS spent fuel pit skimmer pump 120 gpm at 100 ft. head, design pressure 50 psig, design temp.-200°F.

Account No.		Description
225.432	Spent Fuel Pit Heat Exchangers	Two shell and tube heat exchangers with carbon steel shell and stainless steel tubes. Design duty of 4.1E6 Btu/hr/ Unit.
225.433	Spent Fuel Pit Demineralizers	Two mixed bed, 27 gpm SS demineralizers, 15 cft, design pres. 150 psig, design temp.-208^{o}F.
225.434	Spent Fuel Pit Filter, Skimmer, and Strainer	One set of filter, skimmer and strainer with design pressure 150 psig, design temp.-200^{o}F.
225.45	Spent Fuel Pit Underwater Lighting System.	One set spent fuel pool lighting system.
225.46	Spent Fuel Pit Surge Tank	One SS 750 cft spent fuel at surge tank. Design pressure 150 psig, design temp.-200^{o}F.
226.112	Nitrogen & Hydrogen Storage Bottles	Ten pressurized storage bottles. Design pressure 2450 psig, design temp.-200^{o}F.
226.5111	Borated Water Storage Tank	One SS 300,000 gal. borated water storage tank, design pressure-Atm., design temp.-200^{o}F.
226.5112	Make Up Pumps	Four horizontal, multistage, centrifugal 85 gpm at 4400 ft. head make up pumps. Design pressure 2100 psig, design temp.-200^{o}F.
226.5113	Make Up Tank	One SS 1550 cft make up tank. Design pressure 150 psig, design temp.-200^{o}F.
226.5121	Boric Acid Recovery	Two 10 gpm SS recovery evaporators. Design Pressure 150 psig, design temp.-200^{o}F.
226.5122	Reactor Coolant Gas Stripper	One 50-200 gpm gas stripper SS, design pressure 75 psig, design temp.-250^{o}F.
226.5123	Boron Analyzer	One Chemical analysis boron analyzer.
226.5131	Evaporator Distillate Test Tanks	Two SS 600 cft vertical cylinder evaporator distillate test tanks, design pressure 4 psig, design temp.-150^{o}F.

Account No.		Description
226.5132	Boric Acid Mix Tank	One SS 100 cft vertical cylinder boric acid mix tank, design pressure Atm., Design temp.-150°F.
226.5133	Concentrate Boric Acid Storage Tanks	Two SS 800 cft horiz. cylinder concentrate boric acid storage tanks, design pressure 4 psig, design temp.-150°F.
226.5134	Reactor Coolant Bleed Hold-Up Tanks	Two SS 6000 cft reactor coolant bleed hold up tanks, design pressure 150 psig, design temp.-200°F.
226.5135	Distillate Storage Tanks	Two SS 6000 cft distillate storage tanks, design pressure 150 psig, design temp.-200°F.
226.5136	LIOH Tank	One SS 10 cft LIOH tank design pressure-Atm., design temp.-200°F.
226.5137	Boric Acid Addition Tank	One 600 cft SS horizontal cylinder boric acid addition tank, design pressure Atm., design temp.-150°F.
226.5138	Caustic Acid Storage Tank	One SS 100 cft caustic acid storage tank, design pressure-Atm., design temp.-150°F.
226.5141	Reactor Coolant Distillate Transfer Pumps	Two centrifugal 200 gpm at 231 ft. head reactor coolant distillate transfer pumps, design pressure 150 psig, design temp.-200°F.
226.5142	Reactor Coolant Bleed Evaporator Feed Pumps	Two centrifugal 60 gpm at 231 ft. head reactor coolant bleed evaporator feed pumps, design pressure 150 psig, design temp.-200°F.
226.5143	Boric Acid Pumps	Two centrifugal 50 gpm at 231 ft. head boric acid pumps, design pressure 150 psig, design temp.-200°F.
226.5144	LIOH Pumps	Three reciprocating piston 10 gph at 231 ft. head LIOH pumps, design pressure 150 psig, design temp.-200°F.
226.5145	Hydrazine Drum Pumps	Two reciprocating piston 10 gph at 231 ft. Head hydrazine pumps, design pressure 150 psig, design temp.-200°F.

Account No.		Description
226.5146	Gas Stripper Pumps	Two centrifugal 70 gpm at 231 ft. head gas stripper pumps, design pressure 150 psig, design temp.-200°F.
226.5147	Gas Stripper Vacuum Pumps	Two SS 20 lbs/hr gas stripper vacuum pumps, design pressure 50 psig, design temp.-200°F.
226.5148	Reactor Coolant Bleed Recirculation Pump	One SS centrifugal 100 gpm at 231 ft. Head reactor coolant bleed recirculation pump, design pressure 150 psig, design temp.-200°F.
226.5149	Reactor Coolant Distillate Test Tank Pumps	Two centrifugal 60 gpm at 231 ft. head reactor coolant distillate test tank pumps, design pressure 150 psig, design temp.-200°F.
226.5211	Purification Demineralizers	Two SS, mixed bed, 15 cft, purification demineralizers at 27 gpm, design pressure 150 psig, design temp.-200°F.
226.5212	Deborating Demineralizers	Three SS, regenerative, 65 cft, 50 gpm deborating demineralizers, design pressure 150 psig, design temp.-200°F.
226.5213	Reactor Coolant Bleed Demineralizers	Two SS, non-regenerative, boric acid saturated, mixed bed demineralizers, 30 gpm, 65 cft, design pressure 150 psig, design temp.-200°F.
226.5311	Make Up and Purification Demineralizer Filters	Four SS, disposable element, 27 gpm, 5 M.A. filters. Design pressure 150 psig, design temp.-200°F.
226.5312	Boric Acid Filters	Two SS, disposable element, 100 gpm, 25 M.A. filters. Design pressure 150 psig, design temp.-200°F.
226.541	Boric Acid Bin and Screw Conveyor	One SS rotary screw and gravity feed boric acid bin and screw conveyor. Design pressure-Atm., design temp.-150°F.
226.611	Component Cooling Water Surge Tank	One carbon steel, 20 cft, surge tank. Design pressure 150 psig, design temp.-225°F.

Account No.		Description
226.612	Component Cooling Water Pumps	Two centrifugal, CS, 1000 gpm at 200 ft. head, component cooling water pumps, design pressure 150 psig, design temp.-225°F.
226.613	Component Cooling Water Booster Pumps	Two vertical centrifugal, 304 SS, 375 gpm at 175 ft. head cooling water booster pumps, design pressure 150 psig, design temp.-225°F.
226.614	Component Cooling Water Electro-magnetic Filter	One 375 gpm electromagnetic filter, design pressure 150 psig, design temp.-225°F.
226.615	Component Cooling Water Heat Exchangers	Two shell and tube, CS/CuNi, Heat exchangers. 1000 gpm shell side, 115°F inlet, 95°F outlet. 1800 gpm tube side, 85 inlet, 105°F outlet, 10×10^6 Btu/hr.
226.711	Demineralized Water Storage Tank	One SS 40 ft. dia., 40 ft. high demineralized water storage tank. Design pressure 25 psig, design temp.-200°F.
226.712	Equipment and Floor Drains Collection Tank	One CS 5000 cft equipment and floor drains collection tank, design pressure Atm., design temp.-200°F.
226.713	Demineralizer Flush Tank	One SS 1000 cft demineralizer flush tank, design pressure 150 psig, design temp.-200°F.
226.714	Cask Decontamination Drain Collection Tank	One 1000 cft SS cask decontamination drain collection tank. Design pressure 150 psig, design temp.-200°F.
226.716	Demineralizer Flush Tank Pump	One SS centrifugal 50 gpm at 200 ft. head demineralizer flush tank pump, design pressure 150 psig, design temp.-200°F.
226.717	Cask Decontamination Drain Pump	One SS centrifugal 50 gpm at 200 ft. head cask decontamination drain pump, design pressure 150 psig, design temp.-200°F.

Account No.		Description
226.718	Cask Decontamination Drain Collection Filter	One SS, disposable element, 50 gpm, 25 M.A. cask decontamination drain collection filter, design pressure 150 psig, design temp.-200°F.
226.721	Letdown Coolers	Two shell and spiral tube, CS/SS letdown coolers. Shell flow 75,000 lbs/hr, 95°F to 154°F, tube flow 8365 lbs/hr, 604°F to 120°F. 4.42×10^6 Btu/hr.
226.731	Sample Coolers	Two shell and tube, CS/SS sample coolers.
227.1	Main Control Room Nuclear Instrumentation Cabinets	Four NIS cabinets, one for each channel, which provides indication, control, and alarm signals for reactor operation and protection.
227.23	Main Control Room Computer	One process computer system.
231.1	Turbine Generator	One tandom 29.9 MWe turbine generator complete with lube oil system, exciter, air cooled generator.
232.111	Water Intake Traveling Screens	Two 8 ft. wide by 38 ft. high screens traveling at 10 fpm. Each screen passes 38,000 gpm at 0.5 pps and is cleaned by a spray system.
232.112	Water Intake Trash Racks and Rakes	Two 8 ft. wide by 38 ft. high trash racks with rakes.
232.113	Water Intake Pumps	Two vertical wet pit pumps 2000 gpm with 2000 HP motor.
232.114	Screen Wash Pumps	Two centrifugal 200 gpm at 200 ft. head screen wash pumps.
232.115	Deicing Water Pumps	Two centrifugal 100 gpm at 30 ft. head deicing water pumps with 10 HP motors.
232.116	Chlorination System	Storage tanks, pumps, control devices, and diffusers provided to inject chlorine into river water as it leaves the traveling screens.

Account No.		Description
232.221	Circulating Water Pumps	Two vertical wet pit 38,000 gpm at 30 ft. head circulating water pumps.
233.1	Condensers	One single pass, 16,400 sq. ft., 3/4 inch BWG tubes, 15 ft. length condenser.
233.211	Condensate Pumps	Two vertical canned 670 gpm at 100 ft. head condensate pumps.
233.213	Condensate Transfer Pump	One horizontal centrifugal 20 gpm, 100 ft. head condensate transfer pumps.
233.22	Condensate Storage Tank	One SS 40,000 gal. condensate storage tank.
233.24	Condensate Polishers	Two 6 ft. dia. condensate polishers with in place regeneration.
233.312	Condenser Vacuum Pumps	Two full capacity condenser vacuum pumps.
233.4	Cooling Tower	One mechanical draft cooling tower with 28 ft. dia., 231 HP fan, static pumping head of 34 ft. water, 2 cell 36,267 gpm.
234.21	Condensate Booster Pumps	Two vertical 670 gpm at 1600 ft. head condensate booster pumps.
234.22	Main Feedwater Pumps	Two 2500 gpm at 1500 ft. suction and 1970 ft. discharge horizontal feedwater pumps.
234.4	Main Steam Bypass Flash Tank	One 454,000 lbs/hr main steam bypass flash tank, design pressure 750 psia, design temperature 550°F.
234.5	Deaerator Open Heat Exchanger	One 454,000 lbs/hr deaerator open heat exchanger tank, design pressure 750 psia, design temp. 550°F.
	PROCESS HEAT SYSTEM	
234.811	Evaporators	3 evaporators, tube & shell; inlet: 267,000 lbs/hr, at 538°F, 700 psia, 1233.5h; outlet: 267,000 lbs/hr at 497°F, 675 psia, 484.9h steam side. On process side: 192,000 lbs/hr, 200°F, 465 psia, 174h inlet; and 190,000 lbs/hr, 465°F, 450 psia, 1204.8h.

Account No.		Description
234.812	Superheaters	3 24" O.D. x 24 ft. long CS tubed superheaters with 2100 SF.
234.813	Drain Reserve Tank	One 10 ft. dia. by 20 ft. long horizontal drain reservoir tank.
234.814	Evaporator Feedwater Heater	One shell and tube feedwater heater shell side inlet: 800,000 lbs/hr, 497°F, 670 psia, 484h, outlet: 403°F, 650 psia, 379h; tube side: 575,000 lbs/hr, 55°F, 480 psia, 24h inlet, and 200°F, 465 psia, 174h outlet.
234.815	Condensate Filter	One SS, disposable element, condensate filter.
234.816	Evaporator Feed Pumps	Two 2500 gpm at 850 psia evaporator feed pumps 400 HP each.
234.817	Letdown Cooler	One tube and shell letdown cooler.
234.818	Condensate Demineralizer	One mixed bed condensate demineralizer.
234.819	Chemical Addition Pumps	Two 25 gpm at 100 ft. head chemical addition pumps.
234.820	Hydrazine Storage Drum	One SS 50 cft hydrazine storage drum.
234.821	Ammonia Hydroxide Tank	One SS 50 cft ammonia hydroxide tank.
234.822	Blowdown Coolers	Three tube & shell blowdown coolers.
234.823	Sample Cooler	One tube & shell sample cooler.
234.824	Process Feed Pumps	Two centrifugal, horizontal process feed pumps.
235.311	Closed Cooling Water Pumps	Three 1000 gpm at 116 ft. head centrifugal closed cooling water pumps.
235.321	Closed Cooling Water Surge Tank	One 200 cft CS closed cooling water surge tank.
235.322	Closed Cooling Water Heat Exchangers	Three shell & tube CS/SS cooling water heat exchangers.

Account No.		Description
235.411	Make Up Water Treatment Clarifier	One 45 ft. dia. by 15 ft. clarifier.
235.421	Make Up Water Treatment Vacuum Filters	Two vacuum filters for dewatering sludge from clarifier.
235.431	Gravity Filters	Four 12 ft. dia. gravity filters.
235.511	Cation Units	Two 11 ft. dia. cation units with neutralization and regeneration systems.
235.521	Anion Units	Two 11 ft. dia. anion units with neutralization and regeneration systems.
235.531	Degasifier	One degasifier.
241.12	Neutral Transformer	One neutral grounding transformer.
241.21	5 KV Switchgear	Two sections of metal clad indoor type switchgear including automatic fast transfer scheme LOGR.
241.22	480 V Motor Control Centers	Twenty class IE motor control centers bracked for 42,000 ampere.
242.12	Station Auxiliary Transformer	One 13.8/4.16 KV station auxiliary transformer.
242.211	Back-Up Auxiliary Transformer	One back-up auxiliary transformer.
242.212	480 V Switchgear	Four 480 V class IE switchgear.
242.311	Battery System	Four-58 cell, 125 Volt, 1250 ampere hour batteries and one-116 cell, 250 V, 750 ampere hour battery complete with seismic racks.
242.321	Auxiliary Diesel Generators	Two 1500 KW diesel generators complete with controls, fuel on storage, and transfer facilities.
242.332	Inverters	Two class IE, 250 V direct, 120/208 V alternating current, 75 KVA inverters.
243.11	Main Control Board	One protective relay panel.

Account No.		Description
243.12	Auxiliary Power and Signal Boards	Class IE, A-C power distribution panels, including power, lighting, and uninterruptible power supply.
243.22	Battery Control and D-C Distribution Panels	Class IE D-C switchboards including ACB's and class IE DC motor control centers.
246.1	Main Generator Bus	Self cooled isolated phase bus between generator and main power transformer, tap and station auxiliary transformer, tap and surge protection equipment, and neutral connection.
	CRANES	
251.11	Turbine Building Crane	One overhead traveling 175/25 ton crane.
251.12	Reactor Service Building Crane	One overhead traveling 250/25 ton crane.
251.13	Fuel Handling Crane	One overhead traveling 125/25 ton crane.
252.111	Station Air Compressors	Three 200 scfm @ 100 psig station service air compressors with control equipment, intercooler, aftercooler, intake filter, receiver, etc.
252.1113	Instrument Air Dryers	Two vertical instrument air dryers.
252.242	Yard Fire Protection System	One fire water storage tank, pumps, controls, etc.
252.31	Auxiliary Boilers	One 25,000 lbs/hr oil fired package boilers with fuel storage facilities, controls.
253.1	Plant Communication System	One PA type plant communication system.
253.2	Fire Detection System	One fire detection system.
	SWITCHYARDS AND TRANSMISSION	
261.11	Generator Step Up Transformer	One 69-13.8 KV generator step up transformer.

Account No.		Description
261.21	69 KV Circuit Breaker & Disconnects	One 69 KV circuit breaker with disconnects.
261.31	69 KV Potential Transformers	Two sets 69 KV potential transformers, structures, and disconnect switches.

3.8 Cost Estimate

The following cost estimate is based upon the cost estimate previously made for the ERDA study of Reference 3-1. However, just as in the case of the plant layout and equipment list description, the major modifications to that previous estimate is due to the particular requirements of the RAAP. Those items which did not change from the ERDA study are included because these are needed to present a self contained estimate and ease of reference. The major differences between the previous and current estimates are outlined below.

Differences between ERDA Estimate of September 1975 and PE-CNSG Plant Cost for RAAP

- o Labor rates for ERDA estimated $14.03/hr average vs. $11.29/hr at RAAP.
- o Material cost taken from ERDA estimate have been escalated approximately five percent to bring up to 4/76 cost.
- o Yard work cost increased due to addition of steam distribution lines and increased cost of general cut and fill (rock conditions) and other site related items.
- o Reactor Service Building cost decreased due to excavation cost included in site work.
- o Pumphouse/makeup, etc. cost decreased due to redesign for cooling towers vs. open cooling.
- o Reactor Plant Equipment cost increased due to addition of Nuclear Steam Supply System equipment (B&W) ($40,000,000).
- o Safeguards Cooling System cost increased due to addition of cooling towers, basins, pumps, etc.
- o T-G cost reduced due to size change from 94.6 MW to 30 MW.

o Circulating Water System increased due to adding cooling towers, etc.

Condensing system reduced - smaller condenser.

Feedwater system reduced - smaller system.

Switchgear cost reduced - smaller system.

Station service equipment reduced - smaller system.

Electric Structures and Wiring increased due to longer duct runs, more cable tray, conduit and wire.

Air, water and steam service system - decreased due to removal of service water pumps vs. piping.

Engineering and Drafting

Increased Engineering and Drafting also fee included with Engineering and Drafting amount.

Increased manhours on Field Supervision, Temporary Facility Construction, Equipment and Construction Services due to longer job.

Escalation at 8 percent (straight).

Interest during Construction at 10% (straight).

SUMMARY OF ESTIMATE

Acct. No.	Description			Amount	Total
	LAND AND LAND RIGHTS			$	$
	Purchase cost of land	(M		125,000	125,000
	STRUCTURES AND IMPROVEMENTS				
	Yard Work (Includes steam	(L	275,030 Mhr	3,401,200	
	distribution lines)	(M		5,190,100	
	Containment Structure	(L	66,920 Mhr	806,300	
		(M		1,945,400	
	Reactor Service Building	(L	644,750 Mhr	6,796.000	
		(M		6,920,000	
	Control Building	(L	23,500 Mhr	247,000	
		(M		310,000	
	Diesel-Generator and Fuel	(L	45,500 Mhr	478,000	
	Oil Building	(M		500,000	
	Process/Turbine Building	(L	40,100 Mhr	445,000	
		(M		545,000	
	Turbine Service Building	(L	39,600 Mhr	416,000	
		(M		430,000	
	Administration Building	(L	14,000 Mhr	147,000	
		(M		155,000	
	Pump Houses/Make-up Water,				
	Circulating Water and	(L	22,360 Mhr	237,000	
	Service Water	(M		128,000	
	Total Structures and	(L	1,171,760 Mhr	12,973,500	
	Improvements, -	(M		16,123,500	29,097,000
	REACTOR PLANT EQUIPMENT				
	Reactor Equipment	(L	31,700 Mhr	411,000	
		(M		40,024,800	
	Reactor Coolant System	(L	4,440 Mhr	56,300	
		(M		8,200	
	Safeguards Cooling System	(L	68,400 Mhr	847,100	
		(M		1,151,300	
	Radioactive Waste Treatment	(L	12,490 Mhr	159,900	
	and Disposal System	(M		878,400	
	Nuclear Fuel Handling and	(L	10,510 Mhr	122,800	
	Storage System	(M		453,400	
	Nitrogen and Hydrogen Gas	(L	900 Mhr	10,600	
	System	(M		31,200	
	Coolant Purification and	(L	47,030 Mhr	563,900	
	Chemical Treatment Systems	(M		613,900	
	Component Cooling System	(L	10,320 Mhr	122,600	
		(M		63,000	
	Miscellaneous Plant Equipment	(L	5,920 Mhr	76,600	
		(M		265,200	

SUMMARY OF ESTIMATE (cont'd)

Acct. No.	Description			Amount	Total
	REACTOR PLANT EQUIPMENT (cont'd)				
	Miscellaneous Suspense Items	(L	20,000 Mhr	234,000	
		(M		30,000	
	Instruments and Controls	(L	57,730 Mhr	653,500	
		(M		436,300	
	Total Reactor Plant	(L	269,440 Mhr	3,258,300	
	Equipment, -	(M		43,955,700	47,214,000
	TG/PROCESS PLANT EQUIPMENT				
	Turbine-Generator Equipment	(L	25,580 Mhr	337,400	
		(M		2,051,900	
	Circulating Water System	(L	73,650 Mhr	874,300	
		(M		1,879,500	
	Condensing System	(L	29,360 Mhr	346,300	
		(M		1,019,100	
	Feedwater System	(L	40,300 Mhr	476,000	
		(M		245,000	
	Evaporator System	(L	36,400 Mhr	411,300	
		(M		2,632,800	
	Other Turbine Plant Equipment	(L	60,380 Mhr	731,500	
		(M		999,900	
	Instrumentation and Control	(L	21,100 Mhr	249,000	
		(M		678,400	
	Total Turbine Plant	(L	286,770 Mhr	3,425,800	
	Equipment, -	(M		9,506,600	12,932,400
	ELECTRIC PLANT EQUIPMENT				
	Switchgear	(L	12,560 Mhr	131,900	
		(M		937,300	
	Station Service Equipment	(L	16,430 Mhr	172,400	
		(M		1,370,600	
	Switchboards	(L	5,710 Mhr	60,000	
		(M		259,400	
	Protective Equipment	(L	6,710 Mhr	70,000	
		(M		70,000	
	Electrical Structures and	(L	265,000 Mhr	2,785,000	
	Wiring Containers	(M		1,595,000	
	Power and Control Wiring	(L	112,980 Mhr	1,188,400	
		(M		1,633,000	
	Total Electric Plant	(L	419,390 Mhr	4,407,700	
	Equipment, -	(M		5,865,300	10,273,000
	MISCELLANEOUS PLANT EQUIPMENT				
	Cranes and Hoists	(L	8,100 Mhr	94,800	
		(M		1,459,100	

SUMMARY OF ESTIMATE (cont'd)

Acct. No.	Description			Amount	Total
	MISCELLANEOUS PLANT EQUIPMENT (Cont'd)				
	Air, Water and Steam Service Systems	(L	19,830 Mhr	232,200	
		(M		355,100	
	Communications Equipment	(L	8,500 Mhr	89,300	
		(M		52,000	
	Furnishings and Fixtures	(L	1,060 Mhr	11,100	
		(M		172,000	
	Total Miscellaneous Plant	(L	37,490 Mhr	427,400	
	Equipment, -	(M		2,038,200	2,465,600
	SWITCHYARDS AND TRANSMISSION	(L	5,150 Mhr	54,000	
		(M		224,000	278,000
	UNDISTRIBUTED COST				
	Engineering, Drafting Services	(M		11,000,000	
	Field Supervision and Job	(L	220,000 Mhr	2,700,000	
	Office Expense	(M		300,000	
	Temporary Facilities	(L	77,000 Mhr	850,000	
		(M		550,000	
	Construction Equipment	(L	75,600 Mhr	840,000	
		(M		2,700,000	
	Construction Services	(L	12,400 Mhr	140,000	
		(M		535,000	
	Total Undistributed	(L	385,000 Mhr	4,530,000	
	Cost, -	(M		15,085,000	19,615,000
	OTHER PLANT COST	(M		3,000,000	3,000,000
	Subtotak, -	(L	2,575,000 Mhr	29,076,700	
		(M		95,923,300	125,000,000
	CONTINGENCY (10%)				12,000,000
	ESCALATION (8%/yr)				78,000,000
	INTEREST DURING CONSTRUCTION (10%/yr)				35,000,000
	Total Estimate, -				$250,000,000
	ITEMS NOT INCLUDED IN ESTIMATE				
	Owner's Cost				
	Construction Premium Time				
	Nuclear Fuel Cost				
	State and Local Taxes				

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
20.	LAND AND LAND RIGHTS					$	$
201.	Land and Privilege Acquisition						
201.1	Allowance for purchase of approximately 50 acres of land including all surveys, privileges, clearing costs, etc.						
	Total Land and Land Rights, -	(M	50	Acres	2,500	125,000	125,000
	STRUCTURES AND IMPROVEMENTS						
	Yard Work						
	General Cut and Fill						
	Cut						
	Earth excavation	(L	8,900	Mhr	12	106,800	
		(M	430,000	Cy	.50	215,000	
	Soft rock excavation	(L	3,800	Mhr	12	45,600	
		(M	45,000	Cy	2.50	112,500	
	Hard rock excavation	(L	51,700	Mhr	12	620,400	
		(M	155,000	Cy	8	1,240,000	
	Fill	(L	52,500	Mhr	12	630,000	
		(M	630,000	Cy	2.50	1,575,000	
		(L	116,900	Mhr		1,402,800	
		(M				3,142,500	
	Clearing Site	(L	3,300	Mhr	12	39,600	
		(M	50	Acres	550	27,500	
	Finish Grading	(L	1,200	Mhr	12	14,400	
		(M	103,000	Cy	.15	15,500	
	Roads, Walks and Parking Areas						
	Plant roads	(L	1,100	Mhr	12	13,200	
		(M	7,500	Sy	4.50	33,800	
	Parking lot	(L	100	Mhr	12	1,200	
		(M	1,100	Sy	2.50	2,800	
	Access road	(L	2,100	Mhr	12	25,200	
	4" black top and 12" base	(M	14,000	Sy	4.50	63,000	
		(L	3,300	Mhr		39,600	
		(M				99,600	

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
						$	$
211.14	Fencing and Gates						
	Permanent fence (7' high + barbed wire) including gates, etc.	(L	500	Mhr	12	6,000	
		(M	2,400	LF	7.00	16,800	
	Gate house	(L	2,500	Mhr	12	30,000	
		(M	Allowance			30,000	
		(L	3,000	Mhr		36,000	
		(M				46,800	
211.15	Sanitary Sewage Facilities						
	Sewage treatment facilities	(L	2,300	Mhr	11.70	26,900	
		(M				27,000	
	Connections between buildings and treating plant	(L	2,700	Mhr	11.60	31,300	
		(M				16,000	
		(L	5,000	Mhr		58,200	
		(M				43,000	
211.16	Yard Drainage						
	Allowance for area drains and on-site roads and railroad drains						
	Pipe and fittings						
	Area drains	(L	2,700	Mhr	11.60	31,300	
	Installation	(M				30,000	
	Excavation and backfill						
	Manholes and catch basins, etc.						
211.17	Yard Lighting						
	Allowance for lighting yard areas, fences, roads, etc.	(L	7,000	Mhr	10.50	73,500	
		(M	70	Fixt.	1,500	105,000	

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
	STEAM PIPING (DISTRIBUTION)					$	$
	PIPE FITTINGS & INSULATION						
	Carbon Steel - A106B						
	24" Nominal, XS, .5 Wall	(M	11,000	LF		400,000	
		(L	61,000	Mhr	11.80	720,000	
		(M				70,000	
	12" Nominal, Sch. 20, 0.25 Wall	(M	12,000	LF		320,000	
		(L	25,000	Mhr	11.80	295,000	
		(M				30,000	
	Ricwell Design Steam Pipe						
	24", XS, .5 Wall - Conduit 32"	(M	425	LF	180	77,000	
		(L	3,000	Mhr	11.80	35,400	
		(M				3,500	
	12", XS, .375 Wall - Conduit 20"	(M	1,000	LF	105	105,000	
		(L	3,700	Mhr	11.80	43,700	
		(M				4,300	
	Insulation						
	Mineral Wool 3" - 4"	(L	22,000	Mhr	18	400,000	
		(M				310,000	
	Earthwork (Pipe)						
	Excavation	(L	125	Mhr	12	1,500	
	(Ricwell Pipe)	(M	250	Cy	.50	100	
	Backfill	(L	55	Mhr	12	700	
		(M	110	Cy	2.50	300	
	Excavation - Boring Under Roads	(L	500	Mhr	12	6,000	
		(M	Allowance			2,000	
	Excavation - Through River	(L	1,700	Mhr	12	20,000	
		(M				10,000	

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
						$	$
	PIPE SUPPORTS						
	Concrete Work						
	Earthwork						
	Excavation (Earth)	(L	500	Mhr	12	6,000	
		(M	1,000	Cy	.50	500	
	Backfill	(L	250	Mhr	12	3,000	
		(M	500	Cy	2.50	1,300	
	Concrete						
	Forms 2' ø Sonotube	(L	2,000	Mhr	9.35	18,700	
		(M	1,200	LF	5	6,000	
	3' ø Sonotube	(M	300	LF	10	3,000	
	Rebar	(L	1,750	Mhr	13	23,000	
		(M	50	Tons	400	20,000	
	Concrete	(L	850	Mhr	8.50	7,200	
		(M	850	Cy	35	29,800	
	Steel & Iron						
	Sliding & Fixed Supports	(L	3,000	Mhr	13	39,000	
		(M	60	Tons	1,500	90,000	
	HOTWELLS						
	Excavation	(L	60	Mhr	12	700	
		(M	120	Cy	.50	100	
	Backfill (Rock or Stone)	(L	50	Mhr	12	600	
		(M	50	Cy	5	300	
	Backfill	(L	25	Mhr	12	300	
		(M	50	Cy	2.50	100	
	Steel & Iron	(L	75	Mhr	13	1,000	
		(M	5	Tons	1,200	6,000	
	MANHOLES						
	Carbon Steel ℄ 1/2"	(L	130	Mhr	13	1,700	
		(M	2	Ea.		9,500	

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
						$	$
	MAINTENANCE ROAD 9200' x 15' W.						
	Clearing Trees, Etc.	(L	460	Mhr	12	5,500	
		(M	7	Acres	550	3,900	
	Excavation For Road	(L	1,400	Mhr	12	16,800	
		(M	70,000	Cy	.75	52,500	
	Road 12" Gravel	(L	3,000	Mhr	12	36,000	
		(M	20,000	Sy	2.50	50,000	
	Total Steam Piping	(L	130,630	Mhr		1,681,800	
		(M				1,605,200	
211.34	Bridges Over Discharge Canal, etc.		None				
211.43	Railroads		None				
	Sediment Control	(L	2,000	Mhr	12	24,000	
		(M				25,000	
	Foundation Investigation and Test Boring	(M				50,000	
	Total Yard Work	(L	275,030	Mhr		3,401,200	
		(M				5,190,100	8,591,300
212.	Containment Structure 44' ø OD x 66' high						
	Substructure						
212.31	Excavation Work Earth excavation						
	Rock excavation						
	Concrete fill		Incl. with Reactor Serv. Bldg.				
	Backfill						
	Dewatering						

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
						$	$
	Concrete Work						
212.331	Formwork						
212.332	Reinforcing steel (Field fabricated)		Incl. with Reactor Serv. Bldg.				
212.333	Structural concrete - including pea gravel leveling concrete						
212.334	Miscellaneous Iron						
	Leveling tees, anchors, etc.						
	Total Substructure, -						
	Superstructure						
212.342	Structural Steel		None				
	Concrete Containment Cylinder Wall						
	Formwork						
212.3411	Exterior wall forms	(L	6,370	Mhr	9.35	59,800	
		(M	9,100	SF	1.00	9,100	
212.3411	Interior wall bracing						
212.3412	Reinforcing Steel	(L	6,120	Mhr	13	79,600	
		(M	175	Ton	400	60,900	
212.3413	Concrete	(L	3,500	Mhr	8.50	29,800	
		(M	1,400	Cy	35	49,000	
212.3415	Rubbing surface	(L	450	Mhr	8.50	3,800	
		(M	9,100	SF	.05	500	
212.3414	Embedded steel	(L	200	Mhr	11	2,200	
		(M				3,000	
		(L	16,640	Mhr		175,200	
		(M				122,500	
	Concrete Dome						
212.3411	Formwork	(L	400	Mhr	9.35	3,730	
		(M	400	SF	1.75	700	
212 3412	Reinforcing Steel	(L	600	Mhr	13	7,800	
		(M	15	Ton	400	6,000	

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
212.3413	Concrete	(L	300	Mhr	8.50	$ 2,550	$
		(M	100	Cy	35	3,480	
212.3415	Rubbing surfaces,	(L	20	Mhr	8.50	170	
	waterproofing, etc.	(M	400	SF	.05	20	
		(L	1,320	Mhr		14,250	
		(M				10,200	
	Interior Concrete Work		None				
	Steel Containment and Components						
212.37	Containment Liner Plate						
	Cylinder and dome						
	Bottom plate and drain sumps						
	Reactor and instrumentation sumps						
	Test channels						
	Piping sleeves						
	Instrumentation sleeves						
	Electrical sleeves						
	Ventilation sleeves						
	Hatch penetrations						
	Fuel transfer penetration						
	Equipment hatch						
	Personnel hatches						
	Construction openings						
	Vacuum box text						
	Channel strength and leak tests						
	Radiographing						
	High pressure test						
	Leak rate test						
	Nelson studs						
	Installation of above	(L	32,300	Mhr	13	419,900	
		(M	520	Ton	3,150	1,638,000	
212.37	Insulation (outside cont.	(L	4,200	Mhr	12	50,400	
	liner)	(M	7,400	SF	22	162,800	
212.37	Expansion bellows for pipe penetrations through containment walls	(L	800	Mhr	13	10,400	
		(M				10,000	
	Total Superstructure, -	(L	55,260	Mhr		670,150	
		(M				1,943,500	
	Building Services						
	Heating						
212.222	Heaters, piping connections, etc.						

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
	Ventilation Systems					$	$
	Containment Recirculation System						
212.223	Fans - 65,000 cfm						
	Motors - 350 hp						
	Installation of fans and motors						
212.224	Cooling water coils						
212.226	Dampers and drives (butterfly valves)						
212.227	Ductwork						
	Filter equipment						
212.229	Automatic Controls						
		(L	7,600	Mhr	11.70	88,900	
		(M				B&W	
	Containment Purge System						
212.223	Air supply fans and motors						
212.225	Ductwork stack and penetrations						
212.227							
212.27	Dampers and drives						
212.228	Piping connections						
212.227	Filter equipment						
212.229	Automatic control						
		(L	2,700	Mhr	11.70	31,600	
		(M				B&W	
	Containment Iodine Removal						
212.223	Fans and drives - 8,000 cfm capacity						
212.227	Filtration equipment						
212.227	Ductwork						
		(L	200	Mhr	11.70	2,340	
		(M				B&W	
	Reactor Shroud and Mechanism Cooling						
212.223	Fans and drives - 15,000 cfm capacity						
212.227	Ductwork	(L	500	Mhr	11.70	5,850	
		(M				B&W	

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
	Hot Pipe Penetrations Ventilating System					$	$
212.223	Equipment						
212.227	Ductwork, pipe, etc.						
		(L	450	Mhr	11.70	5,260	
		(M				B&W.	
	Total Ventilation Systems, -	(L	11,450	Mhr		133,950	
		(M				B&W	
212.24	Lighting and Service Wiring						
	Power and control equipment						
	Conduit and trays						
	Wire and cable						
	Fixtures						
		(L	210	Mhr	10.50	2,200	
		(M				1,900	
	Total Building Services, -	(L	11,660	Mhr		136,150	
		(M				1,900	
	Total Containment Structure	(L	66,920	Mhr		806,300	
		(M				1,945,400	2,751.700
215.	Reactor Service Building						
	Substructure and Superstructure						
215.11	Excavation Work						
	Earth excavation						
	Rock excavation						
	Concrete fill (or caissons)		Included with Site Work				
	Backfill						
	Dewatering						
	Concrete Work (Base Mat)						
215.1411	Formwork	(L	2,450	Mhr	9.35	22,900	
		(M	3,500	SF	1	3,500	

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
						$	$
215.1412	Reinforcing Steel	(L	14,100	Mhr	13	183,300	
		(M	470	Ton	400	188,000	
215.1413	Structural concrete	(L	6,240	Mhr	8.50	53,000	
		(M	4,800	Cy	35	168,000	
215.1415	Floor finish	(L	1,000	Mhr	8.50	8,500	
		(M	20,000		.10	2,000	
215.1415	Misc. Iron	(L	1,000	Mhr	13	13,000	
		(M	10	Ton	1,300	13,000	
		(L	24,790	Mhr		280,700	
		(M				374,500	
	Miscellaneous Iron						
215.142	Frames, curb angles,	(L	1,200	Mhr	13	15,600	
	anchor bolts, etc.	(M	15	Ton	1,100	16,500	
	Stair treads	(L	800	Mhr	13	10,400	
		(M	400	Ton	14	5,600	
	Floor grating, chk'd.	(L	400	Mhr	13	5,200	
	plate, etc.	(M	2,000	SF	3.50	7,000	
	Handrailing	(L	1,120	Mhr	13	14,600	
		(M	1,400	LF	8.50	11,900	
	Struct. Steel	(L	28,000	Mhr	13	364,000	
		(M	2,000	Ton	900	1,800,000	
		(L	31,520	Mhr		409,800	
		(M				1,841,000	
217.134	Miscellaneous Iron						
	Floor plates in decon-	(L	2,020	Mhr	13	26,300	
	tamination room	(M	500	SF	13	6,500	
	Stainless steel lining in						
	storage pool including	(L	10,600	Mhr	13	137,800	
	gate, etc.	(M	80	Ton	5,300	424,000	
	Miscellaneous iron embedded						
	in concrete including anchor						
	bolts, curb angles,	(L	3,200	Mhr	13	41,600	
	anchors, etc.	(M	40	Ton	1,300	52,000	
		(L	15,820	Mhr		205,700	
		(M				482,500	

ESTIMATE OF COST

ACCT NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
	Concrete Work					$	$
	Formwork - wood	(L	259,000	Mhr	9.35	2,421,700	
		(M	370,000	SF	1	370,000	
	Reinforcing steel	(L	63,000	Mhr	13	819,000	
		(M	2,100	Ton	400	840,000	
	Concrete	(L	57,000	Mhr	8.50	484,500	
		(M	28,500	Cy	35	997,500	
	Rubbing surfaces	(L	9,000	Mhr	8.50	76,500	
		(M	180,000	SF	.05	9,000	
	Forms-metal	(L	7,770	Mhr	9.35	72,600	
		(M	111,000	SF	1.60	177,600	
	Embedded Metal	(L	6,000	Mhr	13	78,000	
		(M	60	Ton	1,300	78,000	
		(L	401,770	Mhr		3,952,300	
		(M				2,472,100	
	Walls, Roof, Etc.						
215.146	Partitions - Block	(L	7,000	Mhr	12.50	87,500	
		(M	28,000	SF	1.50	42,000	
215.147	Sash and glazing	(L	70	Mhr	10.50	700	
	(Lead window)	(M	Allowance			7,500	
215.147	Personnel doors and	(L	810	Mhr	10.50	8,500	
	hardware	(M	950	SF	10.50	10,000	
215.147	Louvres		None				
215.149	Painting	(L	16,000	Mhr	10.30	164,800	
		(M	200,000	SF	.10	20,000	
215.145	Roofing and flashing,	(L	1,930	Mhr	10.50	20,300	
	waterproofing, etc.	(M	27,600	SF	1.80	49,700	
	Painting-Struc. Steel	(L	10,000	Mhr	10.30	103,000	
		(M	2,000	Ton	6.50	13,000	
		(L	35,810	Mhr		384,800	
		(M				142,200	
	Total Substructure and	(L	509,710			5,233,300	
	Superstructure, -	(M				5,312,300	
	Building Services						
	Plumbing and Drains						
215.212	Roof drains	(L	1,350	Mhr	11.80	15,900	
		(M	10	Ea.	850	8,500	
215.211	Floor drains	(L	7,500	Mhr	11.80	88,500	
		(M	100	Ea.	550	55,000	

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
215.211	Sump pump and other equipment	(L (M (L (M	800 4 9,650	Mhr @ Mhr	12 2,500	$ 9,600 10,000 114,000 73,500	$
215.22	Heating Equipment and piping connections Ductwork Insulation						
215.223	Ventilation Equipment and controls						
215.227	Ductwork Air conditioning	(L (M	96,000	Mhr	11.70	1,123,200 1,150,000	
	Fire Protection System Hoses, hose reels, racks, etc.						
215.232	Piping, valves, sprinklers, etc.	(L (M	6,340 Allowance	Mhr	12	80,400 55,000	
215.24	Lighting and Service Wiring Power and control equipment Conduit						
	Trays	(L (M	20,550 137,000	Mhr SF	10.50 1.60	215,800 219,200	
	Wire and cable						
	Fixtures						
	Elevator	(L (M	2,500	Mhr	11.70	29,300 110,000	
	Total Building Services, -	(L (M	135,040	Mhr		1,562,700 1,607,700	
	Total Reactor Service Building, -	(L (M	644,750	Mhr		6,796,000 6,920,000	13,716,000
	Control Building 30' x 60' x 103'h 7200 SF (floor area) 185,000 CF	(L (M	23,500	Mhr	10.50	247,000 310,000	

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION	QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
	Diesel-Generator and Fuel Oil Building				$	$
	D-G Bldg. 70' x 67' x 61'h					
	F-O Bldg. 39' x 33' x 28'h					
	6,000 SF (floor area) (L	45,500	Mhr	10.50	478,000	
	322,100 CF (M				500,000	
	Administration Building					
	76' x 76' x 17'h					
	5,800 SF (L	14,000	Mhr	10.50	147,000	
	98,200 CF (M				155,000	
	Turbine Services Building					
	50' x 82' x 54'h					
	16,400 SF (L	39,600	Mhr	10.50	416,000	
	221,400 CF (M				430,000	
	Make-up Water Pump House					
	11' x 35' x 23'h (L	7,470	Mhr		82,000	
	(M				53,000	
	Circulating Water Pump House					
	Below Grade - 20'w x 30'l x 20' deep					
	Above Grade - 20'w x 15'l x 20' high (L	6,950	Mhr		73,000	
	(M				35,000	
	Service Water Pump House					
	10'w x 15'l x 20' deep (L	7,940	Mhr		82,000	
	(M				40,000	
	Process/Turbine Building					
	Grade Level = 110' x 70' x 55'h					
	58' x 18' x 20'h					
	Basement = 70' x 52' x 23'h					
	12,500 SF					
	529,000 CF					
	Substructure (L	12,500	Mhr	12.40	155,000	
	(M	12,500	SF	8.50	106,000	
	Superstructure (L	17,000	Mhr	9.90	168,000	
	(M	529,000	CF		355,000	
	Building Services (L	10,600	Mhr	11,50	122,000	
	(M	529,000	CF		84,000	
	Total Process/Turbine Building (L	40,100	Mhr		445,000	
	(M				545,000	
	Total Structures and Improvements, - (L	1,171,760	Mhr		12,973,500	
	(M				16,123,500	29,097,000

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
22.	REACTOR PLANT EQUIPMENT					$	$
221.	Reactor Equipment						
	Equipment Components	(M				B&W	
221.12	Reactor vessel shell	(L	2,000	Mhr	13	26,000	
	(225 Ton)	(M				2,600	
221.12	Reactor vessel head	(M				B&W	
	including bolting, etc.	(L	500	Mhr	13	6,500	
		(M				700	
221.13	Upper and lower internals	(M				B&W	
	and thermal shield	(L	28,000	Mhr	13	364,000	
		(M				20,000	
		(L	30,500	Mhr		396,500	
		(M				23,300	
221.11	Supports		With Containment Building				
	Insulation						
221.126	Lower vessel insulation	(M				B&W	
		(L	1,200	Mhr	12.10	14,500	
221.126	Reactor head insulation	(M				1,500	
	B&W Equip. Package	(M				40,000,000	
		(L	Included with work items				
	Reactor Control Equipment						
221.212	Control rod drives						
	Installation		Included with Internals				
221.211	Control rods						
	Installation (preoperational)						
221.43	Control Rod Drive Missile Shield		None				
	Total Reactor Equipment, -						
		(L	31,700	Mhr		411,000	
		(M				40,024,800	40,435,800

ESTIMATE OF COST

ACCT NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
222.	Reactor Coolant System					$	$
	Equipment Components						
222.111	Coolant pumps & motors- gpm @ FTDH-motors		Included with Reactor Vessel Head				
222.131	Steam generators		Included with Reactor Vessel				
		(M	1			B&W	
222.141	Pressurizer and heater	(L	1,040	Mhr	13	13,500	
		(M				1,400	
222.143	Pressurizer relief tank		None				
		(M				B&W	
	Pressurizer Spray Pumps	(L	600	Mhr	12	7,200	
		(M				700	
	Suppression Tanks	(M				B&W	
		(L	2,000	Mhr	13	26,000	
		(M				2,600	
		(L	3,640	Mhr		46,700	
						4,700	
	Supports						
222.114	Coolant pump supports						
222.136	Steam generator supports						
222.141	Pressurizer support		With Equipment				
222.143	Relief tank support						
222.136	Steam generator shields						
222.141	Pressurizer shield						
222.12	Piping						
	Reactor Coolant and Reactor Coolant By-Pass Pipe and fittings including shop fabrication - 30" I.D. Stainless steel						
	Valves					None	
	Hangers and supports						
	Miscellaneous piping materials						
	Erection, welding, testing and cleaning						
	Preheating and stress relieving						
	Radiographing						

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
	Pressure Surge Line and					$	$
222.12	Pressurizer Relief Line						
	Stainless steel pipe & fittings fabricated						
	Control and relief valves	(M				B&W	
	Hangers and supports	(L	300	Mhr	11.80	3,500	
	Installation and Welding	(M				1,400	
222.11	Insulation						
222.13	Equipment insulation						
222.14		(L	500	Mhr	12.10	6,100	
222.12	Piping insulation	(M				2,100	
	Total Reactor Coolant System, -	(L	4,440	Mhr		56,300	
		(M				8,200	64,500
223.	Safeguards Cooling Systems						
223.1	Residual Heat Removal System						
223.111	Residual heat removal pumps - gpm @ 500 gpm @ 675, psig FTDH/hp motor drives	(M	2	Ea.		B&W	
	Installation	(L	300	Mhr	12	3,600	
		(M				200	
223.121	Residual heat removal heat exchangers	(M	2	Ea.		B&W	
	Installation	(L	600	Mhr	13	7,800	
		(M				200	
223.14	Piping connections including pipe, fittings, fabrication, valves, hangers, erection,	(L	4,050	Mhr	11.80	47,800	
	welding, testing, etc.	(M				27,300	
223,15	Insulation						
	Equipment and piping	(L	300	Mhr	12.10	3,600	
		(M				2,200	
	Total Residual Heat	(L	5,250	Mhr		62,800	
	Removal System, -	(M				29,900	

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION	QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
223.3	Coolant Injection and Core Spray System 1750 gpm @ 2260 FTDH 1350 hp motors Installation	None			$	$
223.312	Recirculation pumps - 3000 gpm @ 400 FTDH/ 400 hp motors Installation	None				
223.331	Accumulator tanks- 10'-0"ø - 20'-0"(+) Installation	None				
223.332	Boron injection tank- 6'-6"ø x 13'-6"(+) Installation	None				
	Emergency Decay Heat Removal Pumps (Aux. Feedwater Pumps) 200 gpm - TDH, 200 HP drives (M (L (M	 4 600	 Ea. Mhr	 12	 B&W 7,200 700	
223.34	Piping connections including pipe fittings, fabrication, valves, hangers, erection, welding, testing, etc.	None				
223.4 223.471	Containment Heat Absorption/ Rejection Systems Containment spray pumps- 2600 gpm @ 400 FTDH/ 350 hp motors Installation	None				
223.473	Spray additive tank- 8'-0"ø x 16'-0" ± Installation	None				
223.474	Piping connections including pipe, fittings, fabrication, valves, hangers, spray nozzles, erection, welding, testing, etc.	None				

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
	<u>Service Water Cooling Tower</u>					$	$
	<u>Basin</u> 75' x 60' x 15' Deep						
	Excavation (Rock)	(L	5,000	Mhr	12	60,000	
		(M	5,000	Cy	8	40,000	
	Backfill	(L	160	Mhr	12	1,900	
		(M	320	Cy	2.50	800	
	Forms	(L	6,440	Mhr	9.35	60,200	
		(M	9,200	SF	1.00	9,200	
	Rebar	(L	1,750	Mhr	13	22,800	
		(M	50	Tons	175	8,800	
	Concrete	(L	500	Mhr	8.50	4,300	
		(M	500	Cy	35	17,500	
	<u>Cooling Tower</u> Mechanical Draft 10,000 gpm 2 cells - 75' x 60' x 35'H	(L	16,700	Mhr	15	250,000	
		(M				750,000	
	<u>Piping</u>						
	Excavation (Rock)	(L	450	Mhr	12	5,400	
		(M	450	Cy	8	3,600	
	Backfill	(L	150	Mhr	12	1,800	
		(M	300	Cy	2.50	800	
	24" I.D. - 3/8" Wall C.S.	(L	30,000	Mhr	11.80	354,000	
		(M	60,000	Lbs.	2.10	126,000	
	24" Valves	(L	400	Mhr	11.80	4,700	
		(M	4	Ea.	20,000	80,000	
	<u>Pumps & Motors</u> Horizontal, 10,000 gpm @ 80' tdh, 300 hp	(L	1,000	Mhr	12	12,000	
		(M	2			80,000	
		(M				4,000	
	Total Service Water Cooling Tower	(L	62,550	Mhr		777,100	
		(M				1,120,700	
	Total Safeguards Cooling Systems	(L	68,400	Mhr		847,100	
		(M				1,151,300	1,998,400

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION	QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
					$	$
224.	Radioactive Waste Treatment & Disposal Systems					
224.1	Liquid Waste Processing					
224.111	Waste Hold-up Tanks					
	800 ft^3, 8'ø x 16'H, SS (M	4	Ea.		B&W	
	Installation (L	400	Mhr	13	5,200	
	(M				500	
224.112	Spent Resin Storage Tank (M	1	Ea.		B&W	
	500 ft^3, 10'ø x 15'H, SS (L	100	Mhr	13	1,300	
	Installation (M				50	
224.113	Reactor Coolant Drain Tank					
	700 ft^3, 10'ø x 15'H, SS (M	1	Ea.		B&W	
	Installation (L	100	Mhr	13	1,300	
	(M				50	
224.114	Chemical Drain Tank					
	400 ft^3, 10'ø x 8'H, SS (M	1	Ea.		B&W	
	Installation (L	100	Mhr	13	1,300	
	(M				50	
224.115	Hot Shower & Laundry Drain Tank					
	400 ft^3, 8'ø x 8'H, SS (M	1	Ea.		B&W	
	Installation (L	100	Mhr	13	1,300	
	(M				50	
224.116	Waste Sump Tanks					
	300 ft^3, 4'ø x 7'-6" H, SS (M	2	Ea.		17,000	
	Installation (L	150	Mhr	13	2,000	
	(M				100	
224.117	Regen. Caustic Mix Tank					
	600 ft^3, 8'ø x 12'H, SS (M	1	Ea.		B&W	
	Installation (L	100	Mhr	13	1,300	
	(M				50	
224.118	Waste Evaporator Feed Tank					
	600 ft^3, 8'ø x 12'H, SS (M	1	Ea.		B&W	
	Installation (L	100	Mhr	13	1,300	
	(M				50	
224.119	Waste Evaporator Distillate Test Tank					
	400 ft^3, 8'ø x 8'H, SS (M	2	Ea.		B&W	
	Installation (L	200	Mhr	13	2,600	
	(M				100	

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
224.120	Waste Evaporator Distillate Storage Tank					$	$
	600 ft^3 - - SS	(M	1	Ea.		13,000	
	Installation	(L	100	Mhr	13	1,300	
		(M				50	
224.121	Waste Evaporator Concentrate Storage Tank						
	500 ft^3 - -	(M	1	Ea.		B&W	
	Installation	(L	100	Mhr	13	1,300	
		(M				50	
224.131	Waste Transfer Pumps						
	100 gpm @ 231'tdh	(M	4	Ea.		B&W	
	Installation	(L	200	Mhr	12	2,400	
		(M				50	
224.132	Resin Transfer Pump						
	50 gpm @ 139'tdh	(M	1	Ea.		B&W	
	Installation	(L	50	Mhr	12	600	
		(M				--	
224.133	Spent Resin Sluice Pump						
	100 gpm @ 231'tdh	(M	1	Ea.		B&W	
	Installation	(L	50	Mhr	12	600	
		(M				--	
224.134	Reactor Coolant Drain Tank Pump & Motor						
	50 gpm @ 200'tdh	(M	2	Ea.		B&W	
	Installation	(L	100	Mhr	12	1,200	
		(M				--	
224.135	Chemical Drain Tank Pump & Motor						
	50 gpm @ 200 tdh	(M	1	Ea.		B&W	
	Installation	(L	50	Mhr	12	600	
		(M				--	
224.136	Laundry & Hot Shower Drain Tank Pump & Motor						
	50 gpm	(M	1	Ea.		B&W	
	Installation	(L	50	Mhr	12	600	
		(M					
224.137	Waste Sump Tank Pumps & Motor						
	50 gpm	(M	4	Ea.		8,400	
	Installation	(L	200	Mhr	12	2,400	
		(M				50	

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
224.138	Regen. Caustic Pump & Motor					$	$
	200 gpm @ 231'tdh	(M	1	Ea.		B&W	
	Installation	(L	50	Mhr	12	600	
		(M				--	
224.139	Waste Evap. Feed Pump & Motor						
	50 gpm @ 50'tdh	(M	1	Ea.		B&W	
	Installation	(L	50	Mhr	12	600	
		(M				--	
224.140	Waste Evap. Distillate Transfer Pump & Motor						
	100'gpm @ 150'tdh	(M	2	Ea.		B&W	
	Installation	(L	100	Mhr	12	1,200	
		(M				50	
224.141	Waste Evap. Concentrate Transfer Pump & Motor						
	50 gpm @ 150'tdh	(M	1	Ea.		B&W	
	Installation	(L	50	Mhr	12	600	
		(M				--	
224.151	Waste Evap. Distillate Demineralizer						
		(M	1	Ea.		B&W	
	Installation	(L	100	Mhr	11.70	1,200	
		(M				50	
224.152	Liquid Waste Demineralizer						
	50 ft^3	(M	1	Ea.		B&W	
	Installation	(L	100	Mhr	11.70	1,200	
		(M				50	
224.153	Evap. Distillate Demineralizer						
	40 ft^3	(M	2	Ea.		B&W	
	Installation	(L	200	Mhr	11.70	2,400	
		(M				100	
224.161	Liquid Waste Filter						
	20 MA	(M	1	Ea.		B&W	
	Installation	(L	50	Mhr	11.70	600	
		(M				50	
224.162	Waste Evap. Feed Filter						
	100 g/25 MA	(M	2	Ea.		B&W	
		(L	100	Mhr	11.70	1,200	
		(M				50	

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
224.171	Reactor Coolant Drain					$	$
	Tank Cooler	(M	1	Ea.		B&W	
		(L	100	Mhr	13	1,300	
		(M				50	
224.181	Evaporator Waste Unit						
	25 gpm @ 60 psig	(M	1	Ea.		B&W	
	Installation	(L	50	Mhr	11.70	600	
		(M				--	
224.191	Containment Sump Tank						
	6'ø x 10'H, SS	(M	1	Ea.		10,500	
	Installation	(L	100	Mhr	13	1,300	
		(M				100	
224.192	Containment Sump Pump & Motor						
	60 gpm @ 150'tdh	(M	2	Ea.		4,200	
	Installation	(L	100	Mhr	12	1,200	
		(M				--	
224.195	Piping Connections Including						
	Pipe fittings, etc.	(L	1,010	Mhr	11.80	11,900	
		(M				46,500	
224.196	Insulation for Piping &						
	Equipment	(L	250	Mhr	12.10	3,000	
		(M				3,700	
	Total Liquid	(L	4,660	Mhr		57,500	
	Waste	(M				105,000	162,500
224.2	Gaseous Waste Processing Equip.						
224.21	Gas Decay Tanks						
	3'6"ø x 12'H	(M	6	Ea.		B&W	
	Installation	(L	600	Mhr	13	7,800	
		(M				200	
224.25	Waste Gas Compressor & Motors						
		(M	4	Ea.		B&W	
	Installation	(L	800	Mhr	11.70	9,400	
		(M				500	
224.26	Gas Analyser	(M	1	Ea.		B&W	
	Installation	(L	50	Mhr	11.70	600	
		(M				--	

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
224.28	<u>Piping Including By-Pass From</u>					$	$
	<u>Condenser Vacuum System</u>	(L	940	Mhr	11.80	11,100	
		(M				4,200	
224.281	<u>Waste Gas Filter</u>						
	200 cfm	(M	1	Ea.		B&W	
	Installation	(L	50	Mhr	11.70	600	
		(M				--	
	Total Gaseous Waste	(L	2,440	Mhr		29,500	
	Process Equipment	(M				4,900	34,400
224.3	<u>Solid Waste Processing Equipment</u>						
224.35	Solid Waste Compactor	(M	Incl. Below				
224.37	<u>Solid Waste Solidifying Agent</u>						
	<u>Injection Unit</u>	(L	2,110	Mhr	11.70	24,700	
		(M				210,300	235,000
224.4	<u>Secondary Plant Waste Processing</u>						
224.411	<u>Mixing & Neutralization Tank</u>						
	800 ft^3, 8'ø x 16'L, 6,000 Gal., 6,700#	(M	1	Ea.		21,000	
	Installation	(L	100	Mhr	13	1,300	
		(M				50	
224.412	<u>Regen. Solution Storage Tank</u>						
	600 ft^3, 8'ø x 12'H	(M	2	Ea.		31,500	
	Installation	(L	200	Mhr	13	2,600	
		(M				100	
224.413	<u>Evaporator Feed Tank</u>						
	800 ft^3, 8'ø x 16'H	(M	1	Ea.		44,100	
	Installation	(L	100	Mhr	13	1,300	
		(M				50	
224.414	<u>Evaporator Distillate Tank</u>						
	400 ft^3, 8'ø x 8'H	(M	2	Ea.		48,300	
	Installation	(L	160	Mhr	13	2,100	
		(M				100	

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
224.415	Evaporator Concentrate Storage					$	$
	Tank 300 ft	(M	1	Ea.		19,400	
	Installation	(L	80	Mhr	13	10,000	
		(M				50	
224.421	Regen. Solution Storage Tank						
	Pump 200 gpm @ 150 psig	(M	2	Ea.		4,200	
	Installation	(L	120	Mhr	12	1,400	
		(M				50	
224.422	Evap. Feed Pump						
	50 gpm @ 50'tdh	(M	1	Ea.		3,200	
		(L	50	Mhr	12	600	
		(M				--	
224.423	Evap. Distillate Transfer Pump						
	100 gpm @ 150'tdh	(M	2	Ea.		8,400	
		(L	100	Mhr	12	1,200	
		(M				100	
224.424	Evap. Concentrate Transfer Pump						
	50 gpm @ 150'tdh	(M	1	Ea.		4,600	
		(L	50	Mhr	12	600	
		(M				--	
224.425	Mix Tank Transfer Pump						
	200 gpm @ 231'tdh	(M	1	Ea.		1,900	
		(L	60	Mhr	12	700	
		(M					
224.426	Mixing Pump						
	200 gpm @ 231'tdh	(M	1	Ea.		2,100	
	Installation	(L	60	Mhr	12	700	
224.431	Evap. Distillate Demineralizer						
		(M	1	Ea.		20,700	
	Installation	(L	200	Mhr	11.70	2,300	
		(M				100	
224.511	Secondary Waste Evaporator						
	Unit	(M	1	Ea.		346,500	
		(L	2,000	Mhr	11.70	23,400	
		(M				1,500	
	Total Secondary Plant Waste						
	Processing	(L	3,280	Mhr		48,200	
		(M				558,200	606,400
	Total Radioactive Waste						
	Treatment & Disposal	(L	12,490	Mhr		159,900	
		(M				878,400	1,038,300

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION	QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
225.	<u>Nuclear Fuel Handling and Storage Systems</u>				$	$
225.1	<u>Fuel Handling Tools and Equipment</u>					
225.11	Fuel Handling building bridge crane - 40 ton capacity	Included with Miscellaneous Plant Equipment				
225.12	Fuel handling tools and accessories (M	Allowance			53,000	
	Handling and storing (L	140	Mhr	11.70	1,600	
225.13	Fuel transfer chute from reactor cavity to fuel storage pool including pipe, valves, handling mechanisms, etc.	None				
	Installation					
	Fuel Elevator (M				63,000	
	(L	420	Mhr	11.70	4,900	
	(M				500	
225.2	<u>Remote Viewing Equipment</u>					
	Television, optical systems, special lighting, etc. (M				B&W	
225.3	<u>Service Platforms and Equipment</u>					
225.31	Fuel Canal manipulator crane (M	1	Ea.		105,000	
	Erection (L	1,000	Mhr	11.70	11,700	
	(M				1,200	
225.32	Spent fuel storage pool manipulator crane and platform	None				
	Erection					
225.4	<u>Fuel Storage, Cleaning and Inspection Equipment</u>					
225.41	New fuel storage racks &					
225.42	Spent fuel storage racks (M				74,000	
	Installation (L	500	Mhr	11.70	5,900	
	(M				600	

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
225.4311	Spent fuel pit cooling pump					$	$
	Installation	(M	2	Ea.		21,000	
		(L	400	Mhr	12	4,800	
		(M				500	
225.4312	Spent fuel pit skimmer						
	pump and motor	(M	1	Ea.		4,200	
	Installation	(L	200	Mhr	12	2,400	
		(M				200	
225.432	Spent fuel pit heat						
	exchanger	(M	2	Ea.		21,000	
	Installation	(L	400	Mhr	13	5,200	
		(M				500	
225.433	Spent fuel pit demineralizer-						
	2'-8"ø x 5'H	(M	2	Ea.		10,500	
	Installation	(L	300	Mhr	11.70	3,500	
		(M				300	
225.434	Spent fuel pit filter,						
	skimmer & strainer	(M				1,600	
	Installation	(L	50	Mhr	11.70	600	
		(M				100	
225.436	Piping connections including						
	pipe, fittings, fabrication,						
	valves, hangers, erection	(L	5,120	Mhr	11.80	60,400	
	welding, testing, etc.	(M				48,300	
	Insulation	(L	150	Mhr	12.10	1,800	
		(M				1,400	
225.4371	Refueling water storage tank		None				
	350,000 gallon capacity						
	Foundation						
225.4372	Refueling water purification						
	pump - 50 gpm	(M	2	Ea.		9,700	
	Installation	(L	200	Mhr	12	2,400	
225.45	Spent fuel pit under-	(L	1,430	Mhr	10.50	15,000	
	water lighting system	(M				15,800	
	Spent Fuel Pit Surge Tank	(L	200	Mhr	13	2,600	
	10'ø x 10'h	(M				21,000	
225.5	Fuel Shipping Containers						
	Shipping containers are not included as a part of this estimate						
	Total Nuclear Fuel Handling						
	and Storage	(L	10,510	Mhr		122,800	
	Systems,-	(M				453,400	576,200

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
226.1	Nitrogen & Hydrogen Gas Systems					$	$
226.112	Nitrogen & Hydrogen Storage Bottles	(M	10	Ea.		24,000	
		(L	400	Mhr	11.70	4,700	
		(M				500	
226.113	Storage Rocks	(M				4,200	
		(L	100	Mhr	11.70	1,200	
		(M				100	
226.116	Distribution Piping	(M				2,400	
		(L	400	Mhr	11.80	4,700	
	Total Nitrogen & Hydrogen Systems	(L	900	Mhr		10,600	
		(M				31,200	41,800
226.5	Coolant Purification & Chemical Treatment Systems						
226.511	Borated Water Storage Tank 300,000 gal. 78,800 lbs.	(M	1	Ea.		142,000	
	Installation	(L	4,330	Mhr	13	56,000	
226.5112	Make-up Pumps & Motors	(M	4	Ea.		B&W	
		(L	800	Mhr	12	9,600	
		(M				500	
226.5113	Make-up Tank 10'ø x 22'H	(M	1	Ea.		B&W	
		(L	100	Mhr	13	1,300	
		(M				100	
226.5121	Boric Acid Recovery Evaporation	(M	2	Ea.		B&W	
	Installation	(L	2,110	Mhr	11.70	24,700	
		(M				2,500	
226.5122	Reactor Coolant Gas Stripper	(M	2	Ea.		B&W	
		(L	1,410	Mhr	11.70	16,500	
		(M				1,600	
226.5123	Boron Analyzer	(M	1	Ea.		B&W	
		(L	350	Mhr	11.70	4,100	
		(M				400	
226.5131	Evap. Distillate Test Tanks 600 ft^3, 8'ø x 12'h	(M	2	Ea.		B&W	
	Installation	(L	200	Mhr	13	2,600	
		(M				100	

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
226.5132	Boric Acid Mix Tank 100 ft^3	(M	1	Ea.		$ B&W	$
	Installation	(L	60	Mhr	13	800	
		(M				50	
226.5133	Concentrate Boric Acid						
	Storage Tank 800 ft^3	(M	2	Ea.		B&W	
	Installation	(L	200	Mhr	13	2,600	
		(M				100	
226.5134	Reactor Coolant Bleed						
	Hold-up Tank 6,000 ft^3,						
	20,000#	(M	2	Ea.		168,000	
	Installation	(L	1,200	Mhr	13	15,600	
		(M				1,600	
226.5135	Distillate Storage Tank						
	6,000 ft^3	(M	2	Ea.		168,000	
	Installation	(L	1,200	Mhr	13	15,600	
		(M				1,600	
226.5136	LiOH Tank 10 ft^3	(M	1	Ea.		3,200	
	Installation	(L	50	Mhr	13	700	
		(M				50	
226.5137	Boric Acid Addition Tank						
	600 ft^3	(M	1	Ea.		B&W	
	Installation	(L	100	Mhr	13	1,300	
		(M				50	
226.5138	Caustic Storage Tank						
	100 ft^3, SS, 900#	(M	1	Ea.		10,500	
	Installation	(L	60	Mhr	13	800	
		(M				100	
226.5141	Reactor Coolant Distillate						
	Transfer Pump & Motor						
	200 gpm, 150' psig	(M	2	Ea.		B&W	
	Installation	(L	120	Mhr	12	1,400	
		(M				100	
226.5142	Reactor Coolant Bleed						
	Evaporator Feed Pump						
	60 gpm	(M	2	Ea.		B&W	
	Installation	(L	100	Mhr	12	1,200	
		(M				100	

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
						$	$
226.5143	Boric Acid Pump & Motor 50 gpm	(M	2	Ea.		B&W 1,200	
	Installation	(L	100	Mhr	12	100	
		(M					
226.5144	LiOH Pump & Motor 10 gpm	(M	3	Ea.		B&W 1,800	
	Installation	(L	150	Mhr	12	50	
		(M					
226.5145	Hydrazine Drum Pump & Motor, 10 gpm	(M	2	Ea.		B&W 1,200	
	Installation	(L	100	Mhr	12	50	
		(M					
226.5146	Gas Stripper Pump & Motor	(M	2	Ea.		B&W 2,400	
	Installation	(L	200	Mhr	12	200	
		(M					
226.5147	Gas Stripper Vacuum Pump & Motor	(M	2	Ea.		B&W 2,400	
	Installation	(L	200	Mhr	12	200	
		(M					
226.5148	Reactor Coolant Bleed Recirculation Pump	(M	1	Ea.		B&W 1,200	
		(L	100	Mhr	12	--	
		(M					
	Reactor Coolant Distillate Tank Pumps	(M	2	Ea.		B&W 600	
		(L	50	Mhr	12	--	
		(M					
226.5211	Purification Demineralizer 30 gpm	(M	2	Ea.		8,400	
		(L	400	Mhr	11.70	4,700	
		(M				500	
226.5212	Deborating Demineralizer 50 gpm	(M	3	Ea.		B&W 7,000	
		(L	600	Mhr	11.70	700	
		(M					
226.5213	Reactor Coolant Bleed Demineralizer 30 gpm	(M	2	Ea.		B&W 4,700	
		(L	400	Mhr	11.70	500	
		(M					

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
						$	$
226.5311	Make-up & Purification Dem. Filter	(M	4	Ea.		B&W	
		(L	200	Mhr	11.70	2,300	
		(M				100	
226.5312	Boric Acid Filter	(M	1	Ea.		B&W	
		(L	50	Mhr	11.70	600	
		(M				50	
226.541	Boric Acid Bin & Screw Conveyor	(M	1	Ea.		2,100	
		(L	400	Mhr	11.70	4,700	
		(M				500	
226.551	Piping, Valves, Etc.	(L	30,440	Mhr	11.80	359,200	
		(M				92,400	
226.552	Insulation	(L	1,250	Mhr	12.10	15,100	
		(M				7,400	
	Total Coolant Purification & Chemical Treatment System	(L	47,030	Mhr		563,900	1,177,800
		(M				613,900	
	<u>Component Cooling System</u>						
	Component Cooling Water Surge Tank 150 gal., 150 psig, CS	(M	1	Ea.		B&W	
		(L	50	Mhr	13	700	
		(M				50	
	Component Cooling Water Pumps & Motors - 1000 gpm @ 200!tdh, 125 hp Motor	(M	2	Ea.		B&W	
		(L	300	Mhr	12	3,600	
		(M				400	
	Component Cooling Water Booster Pumps & Motors 375 gpm @ 175'tdh, 30 hp Motor	(M	2	Ea.		B&W	
		(L	150	Mhr	12	1,800	
		(M				200	
	Component Cooling Water Electromagnetic Filter	(M	1	Ea.		B&W	
		(L	50	Mhr	11.70	600	
		(M				50	

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
	Component Cooling Water Heat						
	Exchangers, 1,000 gpm,	(M	2	Ea.		$ B&W	$
	90 CuN Tubes	(L	500	Mhr	13	6,500	
		(M				700	
	Piping	(L	9,020	Mhr	11.80	106,400	
		(M				59,400	
	Insulation	(L	250	Mhr	12.10	3,000	
		(M				2,200	
	Total Component Cooling	(L	10,320	Mhr		122,600	
	Water System	(M				63,000	185,600
	Miscellaneous Plant Equipment						
	Demineralized Water Storage						
	Tank 40'ø x 40'h, SS	(M	1	Ea.		176,000	
		(L	4,800	Mhr	13	62,400	
		(M				6,000	
	Equipment & Floor Drains						
	Collection Tank	(M	1	Ea.		21,000	
		(L	200	Mhr	13	2,600	
		(M				200	
	Demineralizer Flush Tank						
	8'ø x 15'L., SS	(M	1	Ea.		21,000	
		(L	200	Mhr	13	2,600	
		(M				200	
	Cask Decontamination Drain						
	Collection Tank						
	6'ø x 8'L, SS	(M	1	Ea.		12,100	
		(L	100	Mhr	13	1,300	
		(M				100	
	Demineralizer Flush Tank	(M	2	Ea.		4,200	
	Pump	(L	200	Mhr	12	2,400	
		(M				200	
	Cask Decontamination Drain						
	Pump & Motor	(M	1	Ea.		4,800	
		(L	100	Mhr	12	1,200	
		(M				100	
	Cask Decontamination Drain						
	Collection Filter	(M	1	Ea.		2,100	
		(L	70	Mhr	11.70	800	
		(M				100	

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
	Letdown Coolers	(M	2	Ea.		$ 12,600	$
		(L	150	Mhr	13	2,000	
		(M				200	
	Sample Coolers	(M	2	Ea.		4,200	
		(L	100	Mhr	13	1,300	
		(M				100	
	Piping, Valves, Insulating Etc.		Incl. With Other Reactor Plant Systems				
	Total-Miscellaneous Plant Equipment	(L	5,920	Mhr		76,600	
		(M				265,200	341,800
226.7	<u>Auxiliaries Cooling Systems</u>						
226.711	Component cooling pumps 1275 gpm @ 150 FTDH/ 200 hp motors Installation		None				
226.721	Component cooling surge tanks Installation		None				
226.761	Component cooling heat exchangers Installation		None				
226.762	Main coolant pump seal water heat exchanger Installation		None				
226.731	Piping connections		None				
226.741	Insulation for piping and equipment		None				
226.9	<u>Miscellaneous Suspense Items</u>						
226.91	Final Alignment and Checking Allowance for miscellaneous checking and adjusting of equipment after initial rotation tests. (This item shall be used as a suspense account. Cost of work should be charged to equipment benefited and this allowance reduced a like amount)				Included Below		

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
						$	$
226.92	Field Painting Allowance for painting of all reactor plant equipment and piping				Included Below		
226.93	Qualification of Welders Cost of qualifying welders and welding procedure				Included Below		
226.94	Preliminary Operating Allowance for stand-by craft labor and expense during plant start-up				Included Below		
	Total Misc. Suspense Items	(L	20,000	Mhr	11.70	234,000	
		(M				30,000	264,000
	Total Other Reactor Plant Equipment,-	(L	84,170			1,007,700	
		(M				1,003.300	2,011,000
227.	Instruments and Controls						
227.1	Nuclear Plant Instruments All flow, temperature and pressure indicating, recording and controlling instrumentation including control valves, panels (piped and wired to terminal blocks), etc. for the following systems:						
	Reactor plant control	(M				B&W	
	Heat transfer	(M				B&W	
	Fuel handling system						
	Radioactive waste system	(M				290,000	
	Radiation monitoring						
	Steam generators	(M				B&W	
	In-core instrumentation	(M				B&W	
	Other nuclear systems instrumentation	(M				B&W	
	Installation	(L	7,100	Mhr	11.80	84,000	
		(M				8,000	
		(L	7,100	Mhr		84,000	
		(M				298,000	

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
227.2	Computer Equipment					$	$
	For complete plant	(L	35,700	Mhr	11	393,000	
		(M				B&W	
227.3	Monitoring Systems						
227.38	Containment Leakage Monitoring System						
	Penetration Pressurization System - Gauges, valves pressure switches, etc.						
	Pipe, fittings, tubing,	(L	640	Mhr	11.80	7,500	
	hangers, supports, etc.	(M				33,300	
	Instrument racks						
	Air manifold tanks						
	Nitrogen bottles, manifold, etc.						
227.5	Instrument and Control Piping						
227.51	Instrument and control piping connections for nuclear plant instrumentation	(L	14,290	Mhr	11.80	169,000	
		(M				105,000	
	Total Instruments and	(L	57,730	Mhr		653,500	
	Controls, -	(M				436,300	1,089,800
	Total Reactor Plant	(L	269,440	Mhr		3,258,300	
	Equipment, -	(M				43,955,700	47,214,000
23.	TURBINE PLANT EQUIPMENT						
231.	Turbine-Generator Equipment						
231.1	Turbine-Generator						
	29.9 MWe single flow non-reheat steam turbine with a direct coupled, 35 MVA, 3,600 rpm, three-phase 60 Hertz, air-cooled synchronous						

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
	generator complete with hydrogen and lube oil systems, seal oil system, stop-throttle valves and piping, reheaters and moisture separators, crossover piping, motors for auxiliary equipment, heat insulation for turbine, and reheater equipment, etc.	(M	1			$ 1,950,000	$
	Erection of above	(L	20,000	Mhr	12.20	244,000	
		(M				24,000	
		(L	20,000	Mhr		244,000	
		(M				1,974,000	
231.2	Foundation and Supports						
231.211	Turbine-Generator Foundation Mat						
231.2111	Excavation - earth						
231.2112	Concrete fill		With Bldg.				
231.2113	Dewatering						
231.2114	Forms	(L	210	Mhr	9.35	2,000	
		(M	300	SF	1.00	300	
231.2115	Reinforcing steel	(L	120	Mhr	13	1,600	
		(M	4	Ton	400	1,600	
231.2116	Concrete	(L	70	Mhr	8.50	600	
		(M	50	Cy	35	1,800	
231.2119	Miscellaneous iron	(L	100	Mhr	13	1,300	
		(M	2	Ton	1,300	2,600	
		(L	500	Mhr		5,500	
		(M				6,300	
231.212	Turbine-Generator Support						
	Reinforced concrete structure above foundation mat.						
231.2124	Forms	(L	3,600	Mhr	9.35	33,700	
		(M	1,800	SF	1.00	1,800	
231.2125	Reinforcing steel	(L	200	Mhr	13	2,600	
		(M	5	Ton	400	2,000	
231.2126	Concrete	(L	160	Mhr	8.50	1,400	
		(M	80	Cy	35	2,800	

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
231.2127	Rubbing Surfaces	(L	60	Mhr	8.50	$ 500	$
		(M	1,000	SF	.05	50	
231.2128	Expansion joint	(L	50	Mhr	13	650	
		(M	100	LF	7	700	
231.2129	Miscellaneous iron	(L	210	Mhr	13	2,750	
		(M	3	Ton	1,300	3,900	
		(L	4,280	Mhr		41,600	
		(M				11,250	
	<u>Reheater and Moisture Separator Supports</u>						
231.221	Structural steel supports above turbine room operating floor	(L	600	Mhr	13	7,800	
		(M	Allow.			8,000	
231.4	<u>Lubricating Oil System</u>						
231.411	Lube oil purification unit and accessories	(M				6,000	
	Installation	(L	200	Mhr	11.70	2,300	
		(M				250	
231.412	Lube oil transfer pump and motor	(M	1			2,000	
	Installation	(L	100	Mhr	12	1,200	
		(M				100	
231.421	Clean and dirty oil storage tanks Installation including foundations, etc.	(L	300	Mhr	13	3,900	
		(M				12,000	
231.422	Interconnecting piping between equipment oil reservoirs and oil purification equipment	(L	600	Mhr	11.80	7,100	
		(M				6,000	
		(L	1,200	Mhr		14,500	
		(M				26,350	
231.431	Automatic spray system for "ire protection at lube oil and hydrogen areas	(L	1,000	Mhr	12	12,000	
		(M				10,000	
231.45	Initial oil supply	(M				4,000	

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
231.5	Gas Systems					$	$
	Hydrogen and CO_2 Equipment						
231.511	Hydrogen and CO_2 bottle storage racks	(L	1,000	Mhr	12	12,000	
231.512	Manifolds at bottle storage racks and piping to turbine-generator area	(M				12,000	
	Total Turbine-Generator Equipment	(L	28,580	Mhr		337,400	
		(M				2,051,900	
	Make-up & Blowdown						
	Earthwork						
	Excavation (earth)	(L	1,250	Mhr	12	15,000	
		(M	2,500	Cy	.50	1,300	
	Excavation (rock)	(L	300	Mhr	12	3,600	
		(M	300	Cy	8	2,400	
	Backfill	(L	1,250	Mhr	12	15,000	
		(M	2,500	Cy	2.50	6,300	
	Select Fill	(L	90	Mhr	12	1,100	
		(M	170	Cy		900	
	Closed Cycle Circulating Water System						
	Make-up & Blowdown Piping						
	Make-up Pipe & Fittings 12"ø CS, Sch. 40,	(L	7,900	Mhr	11.80	93,000	
	3,000 LF	(M	165,000	Lbs	.75	124,000	
	Valves	(L	100	Mhr	11.80	1,100	
		(M	2	Ea.		4,800	
	Blowdown Pipe & Fittings, 6"ø, CS, Sch. 40,	(L	3,400	Mhr	11.80	40,100	
	3,000 LF	(M	60,000	Lbs	.75	45,000	
	Valves 6"ø	(L	50	Mhr	11.80	600	
		(M	2	Ea.		2,100	
	Pumps & Motors						
	2,000 gpm, 2,000 hp motor	(L	1,400	Mhr	12	16,800	
	Vertical	(M	2	Ea.		21,000	
		(M				1,700	
	Handling Equipment						
	Traveling Water Screens	(L	500	Mhr	12	6,000	
		(M	Allow			30,000	

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
	Trash Racks & Rake	(L	670	Mhr	12	$ 8,000	$
	2 Bays	(M	Allow.			22,000	
	Stop Logs	(L	30	Mhr	12	400	
		(M	Allow.			5,400	
	<u>Water Treatment</u>						
	Make-up Water Treatment	(M				715,000	
		(L	30,000	Mhr	11	330,000	
		(M				33,000	
	<u>Circulating Water Intake & Discharge</u>						
	<u>Earthwork</u>						
	Excavation (earth)	(L	None				
		(M					
	Excavation (rock)	(L	1,900	Mhr	12	22,800	
		(M	1,900	Cy	8	15,200	
	Select Fill	(L	160	Mhr	12	1,900	
		(M	160	Cy	5	800	
	Backfill	(L	600	Mhr	12	7,200	
		(M	1,200	Cy	2.50	3,000	
	<u>Piping Work</u>						
	42"ø RCP-SP-5	(M	1,100	LF		55,000	
	42"ø Fittings	(M	8	Ea.		13,000	
	42"ø Butterfly Valves	(M	2	Ea.		60,000	
	Installation	(L	5,000	Mhr	11.80	59,000	
		(M				6,000	
	42"ø Expansion Joints	(M	4	Ea.	7,000	28,000	
	<u>Pumps & Motors</u>						
	18,000 gpm, 400 hp motors, horizontal	(L	1,400	Mhr	12	16,800	
		(M	2	Ea.		102,000	
		(M				1,700	

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
	Cooling Tower (Condenser)					$	$
	Mechanical Draft Cooling Tower 120'L x 70'W x 52.5'H, Fan hp 231, Fan ø 28', Static Pumping head 34' of Water, 2 cell 36,267 gpm	(L	7,300	Mhr	16.50	120,000	
		(M				495,000	
	Basin 120'L x 70'W x 5' Deep						
	Excavation (Rock)	(L	4,300	Mhr	12	51,600	
		(M	4,300	Cy	8	34,400	
	Backfill	(L	200	Mhr	12	2,400	
		(M	400	Cy	2.50	1,000	
	Forms	(L	3,150	Mhr	9.35	29,500	
		(M	4,500	SF	1	4,500	
	Reinforcing	(L	2,100	Mhr	15	27,300	
		(M	60	Ton	400	24,000	
	Concrete	(L	600	Mhr	8.50	5,100	
		(M	600	Cy	35	21,000	
	Total Closed Cycle	(L	73,650	Mhr		874,300	
	Circulating Water System	(M				1,879,500	2,753,800
	Condensing System						
	Condenser 44,200 SF, Two Pass, shop tube	(M	1			365,000	
		(L	10,700	Mhr	11.70	125,000	
		(M				12,000	
	Condensate Pumps 670 gpm @ 100'tdh, 20 hp	(L	600	Mhr	12	7,200	
		(M	2			20,000	
	Condensate Transfer Pump 20 gpm @ 100'tdh, 5 hp	(L	200	Mhr	12	2,400	
		(M	1			2,000	
	Condensate Storage Tank 40,000 gallon cap.	(L	200	Mhr	13	2,600	
		(M	1			10,000	

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
	Condensate Polishing System	(L	2,800	Mhr	11.70	$ 33,000	$
		(M				220,000	
	Condensate Booster Pumps						
	670 gpm @ 1600'tdh, 350 hp	(L	800	Mhr	12	9,600	
		(M	2			60,000	
	Condensate Piping	(L	10,000	Mhr	11.80	118,000	
		(M				50,000	
233.24	Insulation	(L	800	Mhr	12	9,600	
		(M				4,800	
233.25	Foundations and Supports						
233.251	Condensate pump foundations						
233.252	Condensate storage tank information						
		(L	190	Mhr		2,000	
		(M	20	Cy		1,400	
233.3	Gas Removal System						
233.31	Mech. 20 scfm						
	Vac. Pumps	(L	300	Mhr	12	3,600	
	for Cond. Gas Removal	M	2			4,000	
233.33	Wtr. Box Priming pumps for circulating water side of condenser 30 scfm						
	Installation	(L	300	Mhr	12	3,600	
		(M	2			6,000	
233.34	Condenser Air Removal Piping						
	Pipe and fittings including shop fabrication						
	Valves						
	Hangers and supports						
	Erection and Welding	(L	1,800	Mhr	11.80	21,200	
		(M				9,000	
233.35	Insulation	(L	170	Mhr	12	2,000	
		(M				900	
	Main Steam Bypass Flash Tank						
	454,000 #/hr, 750 psia, 550^oF	(L	200	Mhr	13	2,600	
		(M	1			79,000	

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
	Deaerating Open Heat Exchanger Tank					$	$
	454,000 #/hr, 750 psia, 550°F	(L	300	Mhr	13	3,900	
		(M	1			175,000	
	Total Condensing System	(L	29,360	Mhr		346,300	
		(M				1,019,100	1,365,400
	FEEDWATER SYSTEM						
234.3	Piping						
234.31	Boiler Feed Piping Includes piping from boiler feed pump discharge through high pressure heaters to steam generators						
	Pipe and fittings including shop fabrication Valves Hangers and supports Erection and welding including preheating, stress relief, etc. Radiographs						
		(L	36,300	Mhr	11.80	428,000	
		(M				220,000	
234.341	Extraction Steam Piping		None				
234.342	Heater Drain and Vent Piping		None				
234.35	Insulation						
	Boiler feed piping	(L	4,000	Mhr	12	48,000	
		(M				25,000	
	Total Feedwater System,-	(L	40,300	Mhr		476,000	
		(M				245,000	721,000
	Evaporator System						
	Equipment						
	Evaporators						
	104"OD x 55'lg., 5240 SF, CS tubes	(L	1,200	Mhr	13	15,600	
		(M	3			900,000	

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
	Superheaters					$	$
	24" OD x 24'lg., 2,100 ST CS tubes	(L	900	Mhr	13	11,700	
		(M	3			300,000	
	Drain Reservoir	(L	400	Mhr	13	5,200	
	10'ø x 20'L	(M	1			415,000	
	Feed Heater (Drain Cooler)	(L	300	Mhr	13	3,900	
		(M	1			64,000	
	Condensate Filter	(L	200	Mhr	12	2,400	
		(M	1			29,000	
	Feed Pumps	(L	900	Mhr	12	10,800	
	2500 gpm @ 850 psia, 400 hp	(M	2			368,000	
	Let-down Cooler	(L	100	Mhr	13	1,300	
		(M	1			34,000	
	Condensate Demineralizer	(L	100	Mhr	13	1,300	
		(M	1			31,000	
	Chemical Addition Pumps	(L	200	Mhr	12	2,400	
		(M	2			3,000	
	Hydrazine Storage Drum	(L	100	Mhr	13	1,300	
		(M	1			6,500	
	Ammonia Hydroxide Tank	(L	100	Mhr	13	1,300	
		(M	1			6,500	
	Blowdown Coolers	(L	300	Mhr	13	3,900	
		(M	3		8,000	24,000	
	Sample Cooler	(L	80	Mhr	13	1,000	
		(M	1			6,500	
	Process Feed Pumps	(L	200	Mhr	12	2,400	
		(M	2			163,000	
	Total Equipment	(L	5,080	Mhr		64,500	
		(M				2,350,500	
	Equipment Foundations	(L	1,280	Mhr	10.50	13,500	
		(M				5,800	
	Evap. Sys. Piping	(L	23,300	Mhr	11.80	275,000	
		(M				196,000	
	Insulation	(L	2,570	Mhr	12	30,800	
		(M				15,000	
	Instrumentation	(L	2,070	Mhr	11.80	24,400	
		(M				65,000	
	Painting	(L	300	Mhr	10.30	3,100	
		(M				500	
	Total Evaporator System	(L	34,600	Mhr		411,300	
		(M				2,632,800	3,044,100

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
235.	Other Turbine Plant Equipment					$	$
235.1	Main Vapor Piping						
235.11	Main Steam Piping Includes main steam lines from steam generators to turbine stop valves; steam to reheaters; steam to feed pump turbines; steam dump system, etc.						
	Pipe and fittings including shop fabrication Valves Hangers and supports Erection and welding including preheating and stress relief, etc. Radiographs	(L	33,000	Mhr	11.80	390,000	
		(M				270,000	
235.13	Insulation	(L	2,400	Mhr	12	28,800	
		(M				17,500	
235.14	Pipe Bridge from Containment Structure to Turbine House						
	Foundations including excavation, forms, reinforcing, concrete, anchor bolts,	(L	160	Mhr	10.50	1,600	
	etc.	(M	10	Cy		700	
	Structural steel and	(L	600	Mhr	13	7,800	
	miscellaneous iron	(M	10	Ton		10,000	
		(L	760	Mhr		9,400	
		(M				10,700	
	Total Main Vapor	(L	36,160	Mhr		428,200	
	Piping,-	(M				298,200	
235.2	Turbine Auxiliaries		None				
235.221	Drains collecting tank Installation		None				
235.222	Moisture separator and reheater drain tanks		None				

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION	QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
					$	$
235.223	Heater drain tank Installation	None				
235.224	Miscellaneous tanks Installation	None				
235.241	Gland seal pumps and motors Installation	None				
235.251	Drip, drain and vent piping from turbine plant equipment, etc.	None				
235.261	Insulation- Equipment	None				
	Piping	None				
235.27	Steel supports for tanks, etc.	None				
235.3	Auxiliaries Cooling System					
235.31	Closed cooling water system pumps and motors Installation					
235.321	Surge tanks for closed cooling water system Installation					
235.322	Heat exchangers for closed cooling water system Installation					
235.33	Cooling Water Piping Closed systems for cooling air compressors, sample coolers, condensate pump motor bearings, etc.					
	Pipe and fittings including shop fabrication Valves Hangers and supports Erection and welding					
	(L	6,520	Mhr		96,200	
	(M				136,700	

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
235.34	Insulation Piping system		None			$	$
235.36	Chemical feed equipment Installation		None				
235.4	Make-up Treatment System		None				
235.41	Water treating plant including pretreatment and demineralizer	(L	7,000	Mhr	11.70	81,900	
	facilities complete	(M	Allow.			525,000	
235.5	Chemical Treatment System						
235.51	Secondary chemical treatment for reactor feedwater	(L	700	Mhr	11.70	8,200	
		(M				20,000	
235.9	Miscellaneous Suspense Items						
235.92	Field painting of turbine plant equipment and piping	(L	10,000	Mhr	11.70	117,000	
235.93	Qualification of welders and welding procedure	(M				20,000	
235.94	Stand-by craft labor and expense during plant start-up						
	Total Other Turbine	(L	60,380			731,500	
	Plant Equipment,-	(M				999,900	1,731,400
236.	Instrumentation and Control						
236.1	Turbine Plant Instruments Main control panels with instrument piped and wired to terminal blocks Local control boards with instruments piped and wired to terminal blocks Control systems for process and auxiliary systems in turbine plant						
	Purchase cost of above	(M				570,000	
	Installation	(L	7,100	Mhr	11.80	83,800	
		(M				8,400	

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
235.4	Instrument and Control Piping					$	$
	Instrument and control piping for turbine	(L	14,000	Mhr	11.80	165,200	
	plant instruments	(M				100,000	
	Total Instrumentation	(L	21,100	Mhr		249,000	
	and Control,-	(M				678,400	927,400
	Total Turbine Plant Equipment,-	(L	286,770	Mhr		3,425,800	
		(M				9,506,600	12,932,400
24	ELECTRIC PLANT EQUIPMENT						
	SWITCHGEAR						
	GENERATING EQUIPMENT SWITCHGEAR						
	GENERATOR DISCONNECT SWITCH	(M				20,000	
	Installation	(L	190	Mhr	10.50	2,000	
		(M				200	
	Neutral Grounding Equipment including Transformer, Resistor, etc.						
	Bushing-Type Current Transformers						
	Potential Transformers, Fuses, etc.						
	Surge Protection Equipment including Lightning Arrestors and Capacitors						
	Exciter Switchgear including Exciter Field Breaker						
	Purchase Cost	(M				11,000	
	Installation	(L	780	Mhr	10.50	8,200	
		(M				800	
	STATION SERVICE SWITCHGEAR						
	5kV-2500 MVA Metal-clad indoor type switchgear including automatic fast transfer scheme logic	(M				393,000	
	Installation	(L	2,800	Mhr	10.50	29,400	
		(M				3,000	

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
	STATION MOTOR CONTROL CENTER					$	$
	480 volt motor control centers	(M	20	Ea.	15,000	300,000	
	Installation	(L	5,990	Mhr	10.50	62,900	
		(M				6,300	
	Class IE 480 volt motor control centers, braced for 42,000 ampere, including qualification and sample testing and guaranteed starter momentary capability						
		(M	10	Ea.	20,000	200,000	
		(L	2,800	Mhr	10.50	29,400	
		(M				3,000	
	Total Switchgear	(L	12,560	Mhr		131,900	
		(M				973,300	1,069,200
	STATION SERVICE & STARTUP TRANSFORMERS						
	Station Auxiliary Transformer	(M				55,000	
	Installation	(L	500	Mhr	10.50	5,300	
		(M				500	
	Back-Up Auxiliary Transformer	(M				68,000	
	Installation	(L	500	Mhr	10.50	5,300	
		(M				500	
	Foundations for Transformers	(L	210	Mhr	9.50	2,000	
		(M				2,100	
	Total Service and Start-Up Transformers						
	Low Voltage Unit Substations and Lighting Transformers						
	Unit Substations and Transformers						
	480 volt substations	(M	5	Ea.	30,000	180,000	
	Installation	(L	4,000	Mhr	10.50	42,000	
		(M				4,000	

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION	QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
	Unit Substations and Transformers				$	$
	Class IE 480 volt substations including qualification and sample testing (M	4	Ea.	40,000	160,000	
	(L	2,000	Mhr	10.50	21,000	
	(M				2,000	
	Total low voltage unit substation and lighting transformers					
	AUXILIARY POWER SOURCES					
	BATTERY SYSTEM					
	Batteries - Class IE 4-48 cell, 125 volt, 1,250 ampere hour batteries and 1-115 cell, 250 volt, 750 ampere hour battery complete with seismic racks including qualification					
	Class IE charging equipment including qualification (M				70,000	
	(L	1,430	Mhr	10.50	15,000	
	(M				1,500	
	Auxiliary Generators					
	1500 kw diesel generators complete with controls fuel oil storage and transfer facilities					
	Automatic sprinkler system					
	Purchase cost (M				720,000	
	Installation (L	6,930	Mhr	10.50	72,800	
	(M				36,000	
	Inverters					
	Class IE - 250 volt direct Current - 120/208 volt alternating current, 75 kVA, with static bypass switch including qualification (M				70,000	
	Installation (L	860	Mhr	10.50	9,000	
	(M				1,000	
	Total Auxiliary Power Sources (L					
	(M					

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
	Total Station Service					$	$
	Equipment	(L	16,430			172,400	
		(M				1,370,600	1,543,000
	Switchboards						
	Main control boards for electric systems						
	Protective relay panel	(M				106,000	
	Installation	(L	1,360	Mhr	10.50	14,300	
		(M				1,400	
	Auxiliary Power and Signal Boards						
	Class IE A-C power distribution panels including power, lighting and uninterruptible power supply panels and qualification of class IE panels	(M				50,000	
	Installation	(L	1,780	Mhr	10.50	18,700	
		(M				2,000	
	Battery Control and D-C Distribution Panels						
	Class IE D-C switchboards including ACBs and qualifications						
	Class IE D-C motor control centers including qualification						
	Class IE D-C power distribution including qualification						
	station battery fuses	(M				97,000	
		(L	2,570	Mhr	10.50	27,000	
		(M				3,000	
	Total switchboards	(L	5,710			60,000	
		(M				259,400	319,400
	Protective Equipment						
	Station grounding system lightning protection						
	Cathodic protection						
	Automatic fire protection for transformers						
	Purchase Cost	(L	6,710	Mhr	10.50	70,000	
	Installation	(M				70,000	140,000

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
	Electrical Structures and Wiring Containers					$	$
	Underground Duct Runs						
	Concrete envelope including excavation, manholes, etc.	(M	15,000	LF	7	105,000	
		(L	15,000	Mhr	10.50	160,000	
	Cable Trays						
	Includes trays, supports, hangers, etc.	(M	40,000	LF	16	640,000	
		(L	700,000	Mhr	10.50	1,050,000	
		(M				50,000	
	Conduit						
	Includes power, control and instrumentation conduit, fittings, etc.	(M	200,000	LF	4	800,000	
		(L	750,000	Mhr	10.50	1,575,000	
	Total Electrical Structures and Wiring Containers	(L	265,000	Mhr		2,785,000	
		(M				1,595,000	4,380,000
	Power and Control Wiring						
	Generator Circuits Wiring						
	Main Generator Bus						
	Self-cooled isolated phase bus between generator and main power transformer, self-cooled isolated phase bus between tap and station auxiliary transformer, tap and surge protection equipment and neutral connection	(M				31,000	
	Installation	(L	1,000	Mhr	10.50	10,400	
		(M				1,000	
	Station Service Power Wiring						
	High voltage cable and bus (1 KV and above)						
	Station and back-up auxiliary transformers to unit and plant switchgear, 5 KV, 1,200 ampere nonsegregated phase bus duct	(M	150	LF	100	15,000	
	Installation	(L	1,620	Mhr	10.50	17,000	
		(M				1,000	

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
	High Voltage Cable (5 KV)	(M	20,000	LF	4	$ 80,000	$
		(L	2,860	Mhr	10.50	30,000	
	Low Voltage Cable and Bus (Below 1 KV)						
	Low voltage cable (480 volts and less)	(M	150,000	LF	3	450,000	
		(L	75,000	Mhr	10.50	160,000	
	Total Station Service Power Wiring						
	Control Wiring						
	Multi-conductor, 1,000 volt	(M	800,000	LF	1	800,000	
		(L	80,000	Mhr	10.50	840,000	
	Instrumentation Wiring						
	Containment Penetrations	(M				250,000	
	Installation	(L	12,500	Mhr	10.50	131,000	
		(M				5,000	
	Total Power and Control Wiring	(L	112,980	Mhr		1,188,400	
		(M				1,633,000	2,821,400
	Total Electric Plant Equipment	(L	419,390	Mhr		4,407,700	
		(M				5,865,300	10,273,000
25.	MISCELLANEOUS PLANT EQUIPMENT						
251.	Transportation and Lifting Equipment		None				
251.1	Cranes and Hoists						
251.11	Overhead traveling crane for turbine room- 175/25 ton capacity	(M	1			110,000	
	Erection	(L	2,000	Mhr	11.70	23,400	
		(M				2,300	
251.12	Polar crane in reactor service building 250 ton capacity, 133'span	(M	1			790,000	
	Erection	(L	3,000	Mhr	11.70	35,100	
		(M				3,500	

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
251.131	Fuel handling crane-125 ton capacity, 133'span	(M	1			$ 525,000	$
	Erection	(L	2,800	Mhr	11.70	32,800	
		(M				3,300	
251.132	Miscellaneous hoists	(L	300	Mhr	11.70	3,500	
		(M				25,000	
251.133	PAB monorail system		None				
	Total - Cranes and Hoists	(L	8,100	Mhr		94,800	
		(M				1,459,100	1,553,900
252.	Air, Water and Steam Service Systems						
252.1	Air Systems						
252.1111	Station service air compressor-200 scfm @ 110 psig with control equipment, inter-cooler, after-cooler, intake filter, receiver, etc.						
	Motor drive						
	Installation	(L	1,200	Mhr	12	14,400	
		(M	3		17,000	51,000	
252.1112	Instrument air compressors-231 scfm @ 100 psig with control equipment, motors, coolers, filters, receivers, etc.		None				
	Foundations	(L	720	Mhr	10.50	7,600	
	Installation	(M	45	Cy	70	3,100	
252.1113	Instrument air dryers	(L	150	Mhr	13	2,000	
		(M	2			8,000	
252.112	Air distribution piping (excludes instrument air and control piping)	(L	2,560	Mhr	11.80	30,200	
		(M				13,000	
	Total Air System	(L	4,630	Mhr		54,200	
		(M				75,100	
252.2	Water Systems		None				
	Service Water System						
252.211	River water supply pumps-etc.		None				
252.291	Service water piping etc.		None				

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
	<u>Yard Fire Protection System</u>					$	$
252.242	Water storage tank including foundations, paintings, etc.						
252.292	Pipe and fittings (10"ø)						
	Hydrants and accessories	(L	11,600	Mhr	11.70	135,700	
	Valves	(M				160,000	
	Hose stations						
	Installation						
	Excavation and backfill						
	<u>City Water Piping</u>						
252.293	Distribution pipe (Excludes	(L	1,700	Mhr	11.80	20,100	
	building plumbing)	(M				10,000	
	Total Water Systems,-	(L	13,300	Mhr		155,800	
		(M				170,000	
252.3	<u>Auxiliary Heating Steam</u>						
252.31	<u>Auxiliary Heating Boilers</u>						
	25,000 #/hr oil fired units complete with fuel storage facilities, fuel and steam piping connections, electrical controls and wiring, boiler enclosure, etc.	(L	1,900	Mhr	11.70	22,200	
		(M				110,000	
	Total Air, Water and Steam Service Systems,-	(L	19,830	Mhr		232,200	
		(M				355,100	587,300
253.	<u>Communications Equipment</u>						
253.1	<u>Local Communications Systems</u>	(L	3,000	Mhr	10.50	31,500	
		(M				10,500	
253.15	Public Address and Inter-Communication System						
	Hand-sets, speakers,	(L	2,000	Mhr	10.50	21,000	
	wire, etc.	(M				19,000	
253.2	<u>Signal Systems</u>						
253.21	Fire detection system	(L	2,000	Mhr	10.50	21,000	
		(M				12,500	
253.25	Noise monitoring system	(L	1,500	Mhr	10.50	15,800	
		(M				10,000	
	Total Communications	(L	8,500	Mhr		89,300	
	Equipment,-	(M				52,000	141,300

ESTIMATE OF COST

ACCT NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
254.	Furnishings and Fixtures					$	$
254.1	Safety Equipment						
254.12	Portable fire extinguishers, fire blankets, etc.	(M				6,500	
254.2	Shop, Laboratory and Test Equipment						
254.21	Machine Shop Equipment						
254.22	Electrical Shop Equipment						
254.23	Chemical Laboratory	(L	200	Mhr	11	2,200	
	Special Laboratory furniture & fixtures	(M				100,000	
	Installation						
254.3	Office Equipment and Furnishings						
254.31	Office furniture	(L	130	Mhr	11	1,400	
254.32	Office equipment	(M				12,000	
254.4	Change Room Equipment						
254.41	Lockers and benches	(L	200	Mhr	11	2,200	
254.42	Laundry facilities	(M				8,500	
254.6	Dining Facilities						
	Cafeteria equipment	(L	530	Mhr	10	5,300	
		(M				45,000	
	Total Furnishings and	(L	1,060	Mhr		11,100	
	Fixtures,-	(M				172,000	183,100
	Total Miscellaneous Plant	(L	37,490	Mhr		427,400	
	Equipment,-	(M				2,038,200	2,465,600
	SWITCHYARDS & TRANSMISSION						
	Power Plant						
	Generator Step-up Transformer, including lightning arrestors and current transformer, 27 MVA, 55 C, 69-13.8 KV	(M				145,000	
	Installation	(L	1,000	Mhr	10.50	10,600	
		(M				1,000	
	69 KV Circuit Breaker & Disconnects	(M				25,000	
	Installation	(L	600	Mhr	10.50	6,400	
		(M				600	

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
	Foundations for above	(L	850	Mhr	10.50	$ 8,900	$
	9 + 6 = 15	(M	57	Yd^3		3,400	
	69 KV Potential Transformers, Structures & Disconnect Switches	(M	2	Sets		20,000	
		(L	250	Mhr	10.50	2,700	
		(M				200	
	<u>Substation 4 RP - Main Power Connection</u>						
	Disconnect Switch & Support Structure	(M				4,000	
	Installation	(L	50	Mhr	10.50	500	
		(M				100	
	Main Power Line to Substation 4 RP	(M	1,500	LF		5,000	
	Installation .4	(L	600	Mhr	10.50	6,300	
		(M				600	
	Poles, insulators & hardware	(M	6	Ea.		3,000	
	Installation 50	(L	300	Mhr	10.50	3,200	
		(M				300	
	<u>Substation ASBL - Stand-by Service Power</u>						
	Disconnect Switch & Support Structure	(M				4,000	
	Installation	(L	50	Mhr	10.50	500	
		(M				100	
	Standby-Service Power Line to Substation ASBL	(M	2,500	LF		6,000	
	Installation .4	(L	1,000	Mhr	10.50	10,500	
		(M				1,000	
	Poles, insulators & hdwre.	(M	9	Ea.		4,000	
	Installation 50	(L	450	Mhr	10.50	4,700	
		(M				400	
	Total Switchyards & Transmission						
		(L	5,150			54,000	
		(M				224,000	278,000

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
91.	UNDISTRIBUTED COSTS					$	$
910.	Engineering, Construction Management and Field Supervision						
910.1	Engineering and Drafting Architect - Engineer services including wages, expense and overhead allowance	(M	571,400	Mhr	17.50	10,000,000	
910.2	Construction Management and Field Supervision Wages, expense and overhead for superintendents, field engineers; cost control, planning and scheduling; safety engineers; craft supervisors and quality control; start-up engineers; accounting, timekeeping, purchasing and material departments; etc.	(L	220,000	Mhr	12.30	2,700,000	
	Job office expense including stationery, office supplies, photographs, employee's relocation expense, etc.	(M				300,000	
910.3	Engineering and Construction Fee	(M				1,000,000	
		(L				2,700,000	
		(M				11,300,000	14,000,000
911.	Temporary Facilities						
911.11	Roads and parking area (access and on-site)						
911.12	Railroads		None				
911.13	Barge unloading slip		None				
911.14	Construction access		None				
911.2	Buildings						
911.31	Electric light and power installation						
911.32	Pipe lines Temp. Protection Snow Removal						
		(L	77,000	Mhr	11.04	850,000	
		(M				550,000	1,400,000

ESTIMATE OF COST

ACCT. NO.	DESCRIPTION		QUANTITY	UNIT	RATES	AMOUNTS	TOTALS
912.	Construction Equipment					$	$
912.1	Rental and depreciation of major equipment	(L (M	75,600	Mhr	11.11	840,000 2,700,000	3,540,000
912.4	Heating plant		None				
912.7	Office furniture and equipment		None				
912.8	Temporary protection, snow removal, etc.		None				
912.82	Purchase of small tools and misc. supplies		Incl.	with	Sub Con	tractors Cost	
913.	Construction Services						
913.11	Charges for electric energy						
913.12	Charges for purchased water						
913.16	Fuel for heating boiler						
913.17	Telephone, telegraph, etc.						
913.21	Watchman and guard service						
913.81	Janitor services	(L (M	12,400	Mhr	11.29	140,000 535,000	675,000
913.82	Set-up, dismantle and maintain construction equipment		None				
913.92	Public liability and property damage insurance premiums						
913.95	First aid expense						
913.96	Builders risk insurance premiums						
	Total Undistributed Costs,-	(L (M	385,000	Mhr		4,530,000 15,085,000	19,615,000
	OTHER PLANT COSTS (UNCLASSIFIED)						
	Licensing and Public Relations Expense	(M				1,000,000	
	Operator Training	(M				500,000	
	Spare Parts	(M				1,500,000	
	Owners' General Office and Administrative Cost					Not Incl.	
		(M				3,000,000	3,000,000
	Subtotal,-						125,000,000
	NORMAL CONTINGENCY		10%				12,000,000
	Subtotal,-						
	ESCALATION (1976 Operation) 8% per yr.						78,000,000
	INTEREST DURING CONSTRUCTION 10% per yr.						35,000,000
	Total Estimate,-						250,000,000

3.9 Plant Drawings

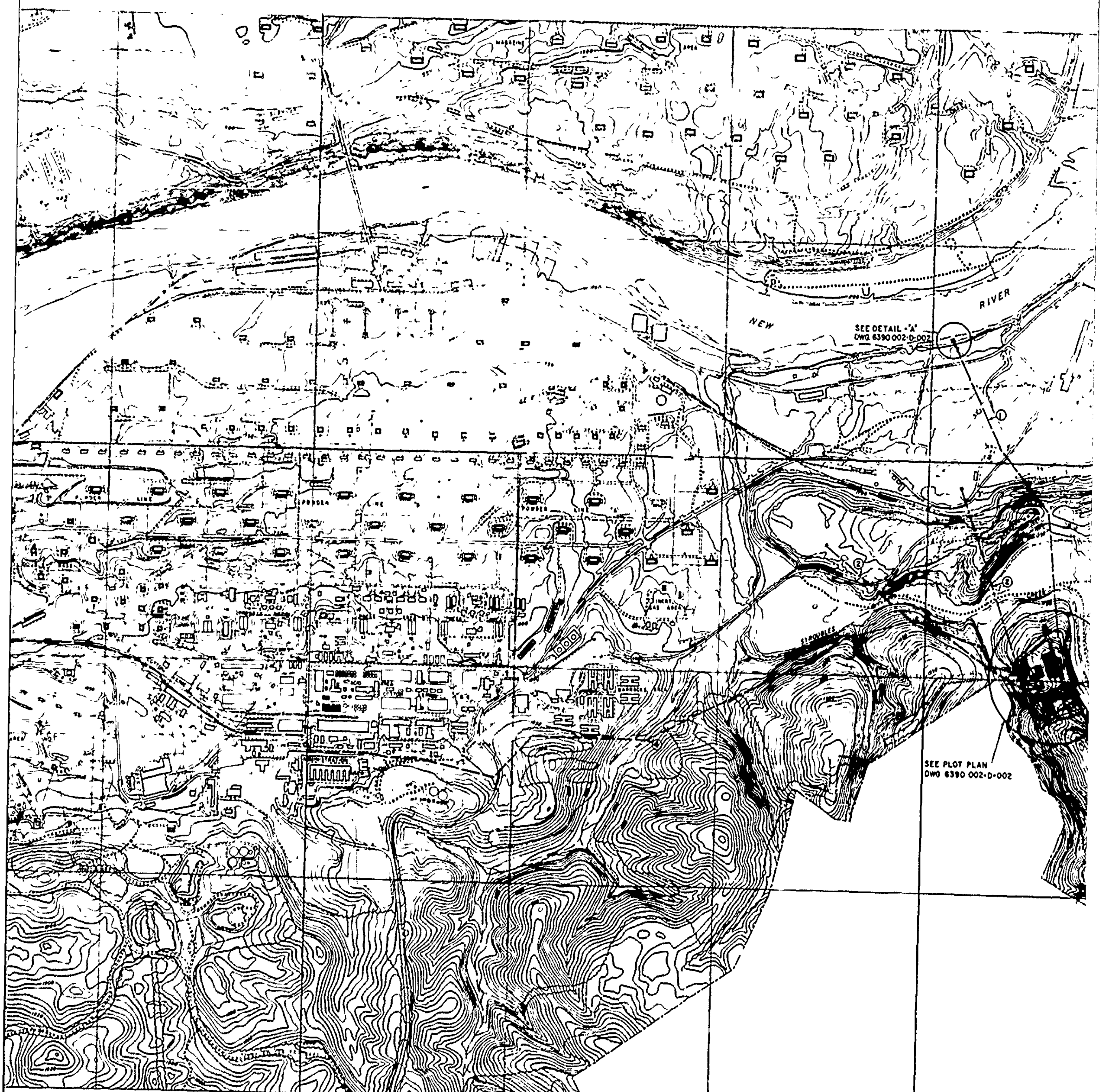
Following is a set of the PE-CNSG plant drawings taken from reference 3.0-1 and modified as required for RAAP. Drawing No. 6390.002-S-001, Site Plan, and 6390.002-D-001, Plot Plan, are only applicable to RAAP. The remainder of the drawings did not require modification and are those which appear in the reference.

In addition to the drawings included in this section, several figures have been used throughout the various sections of this report. It should be mentioned that Figures Nos. 3-2 and 3-3 were developed by Babcock and Wilcox and were not originated in this study.

Section 3.0 REFERENCES

3.0-1 A Small Pressurized Water Reactor for Process Energy. BAW-1428, ORNL-Sub-4390-2 June, 1976.

NEW
RIVER
NEW
RIVER
NEW
POWDER
LINE



NEW
RIVER
SEE DETAIL "A"
DWG 6390 002-D-002
SEE PLOT PLAN
DWG 6390 002-D-002

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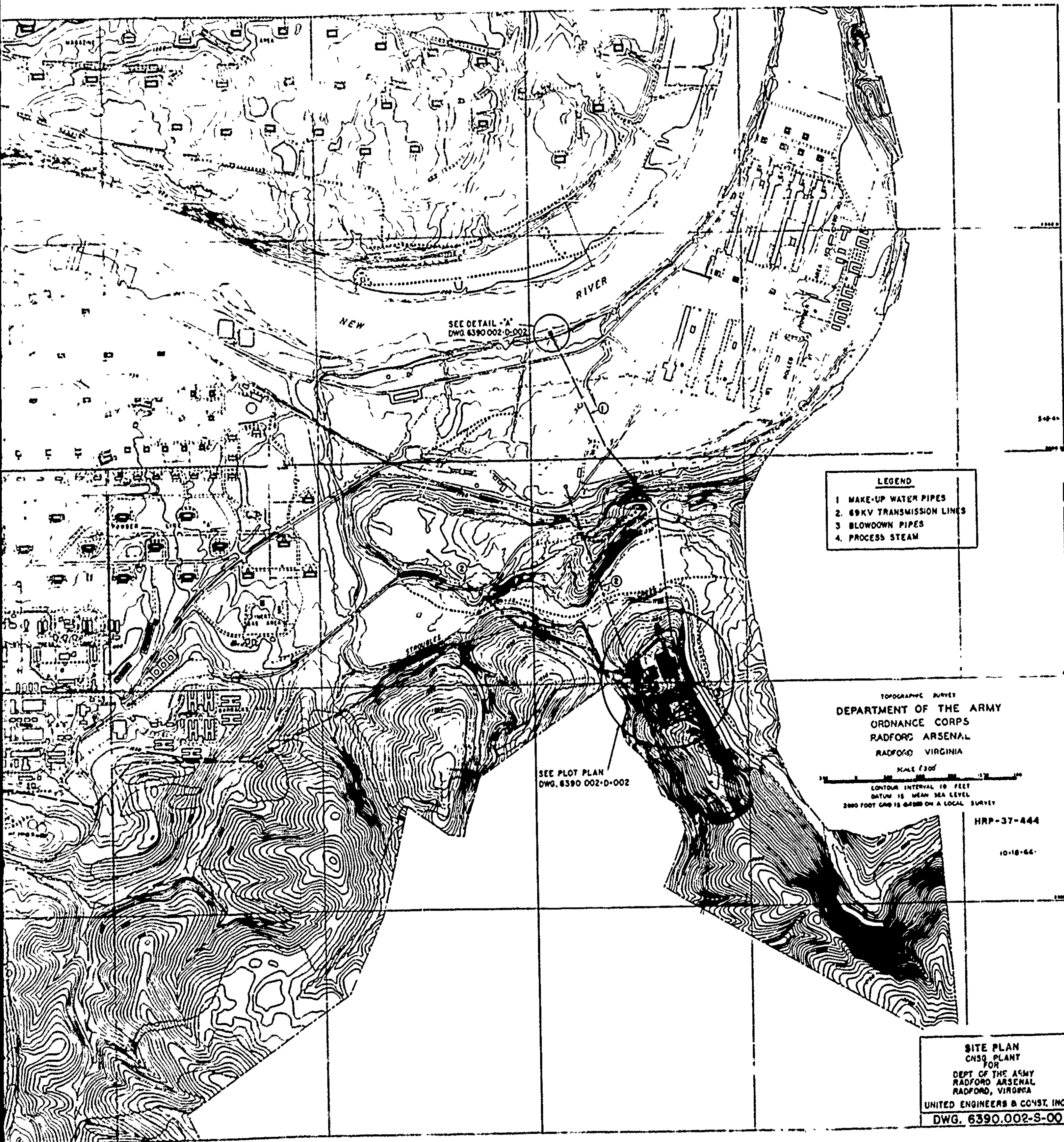

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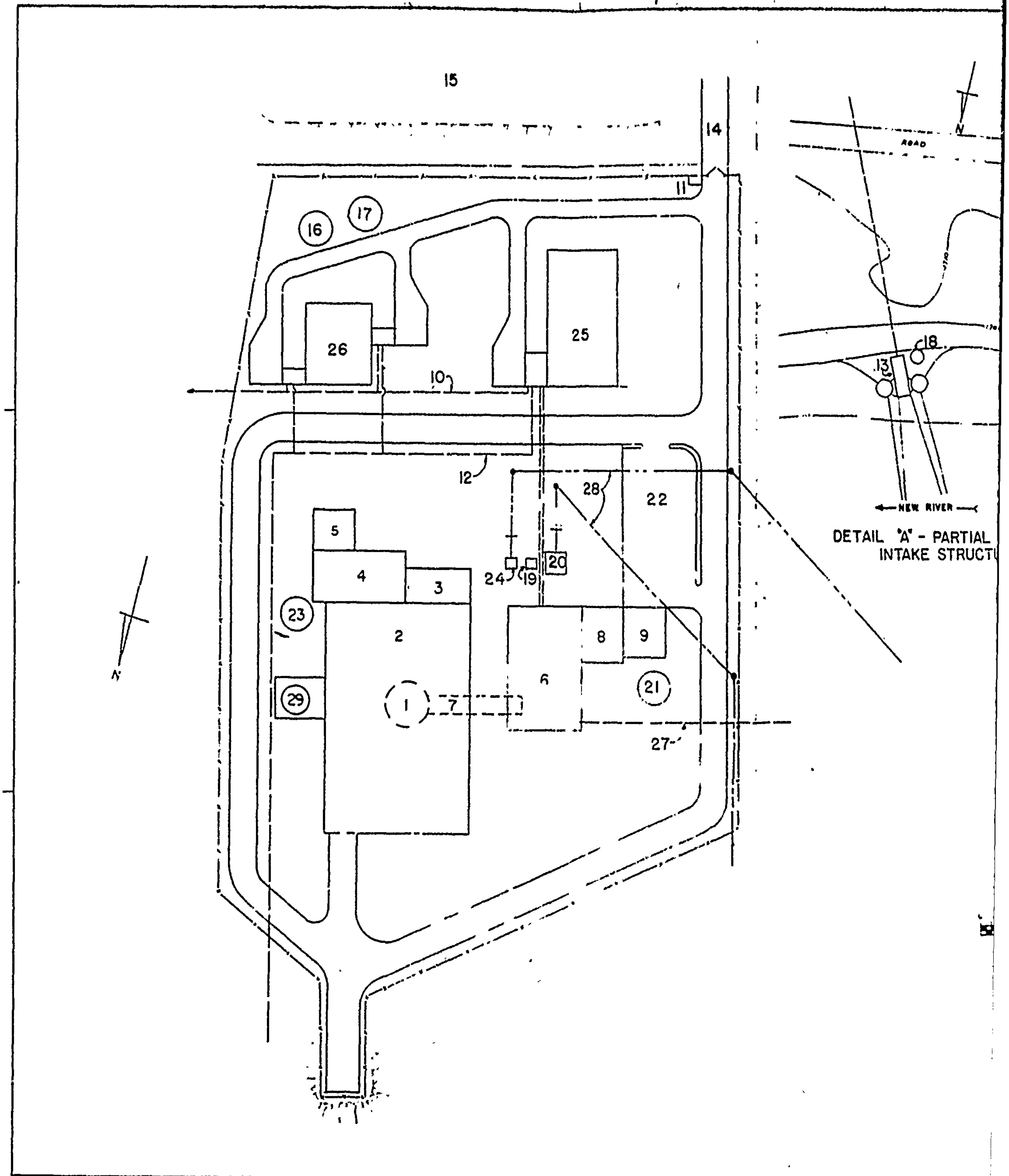

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ROAD
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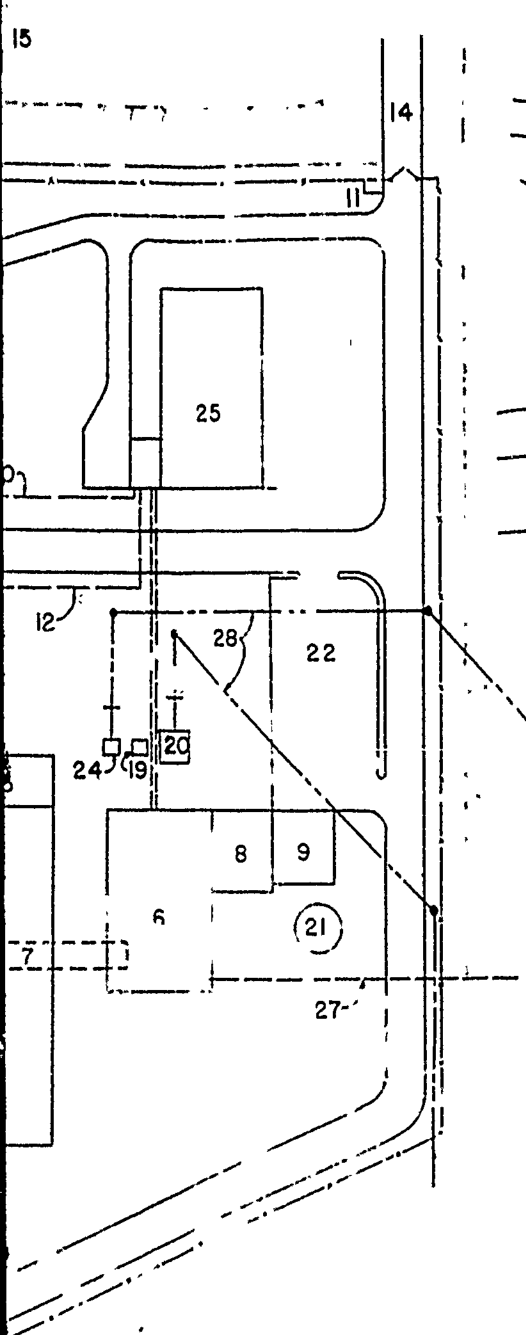
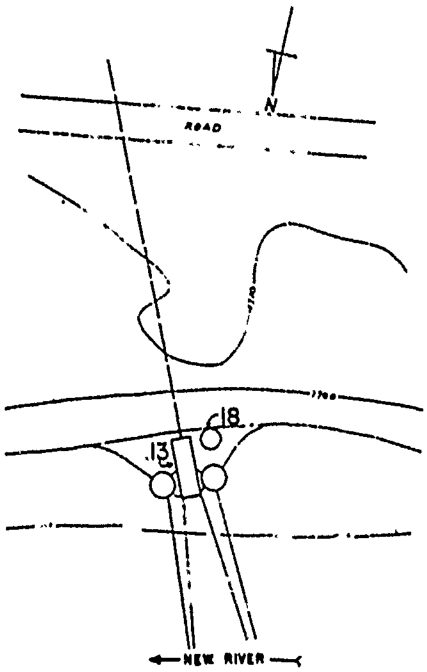
NEW RIVER
N
DETAIL 'A' - PARTIAL
INTAKE STRUCTU





DETAIL "A" - PARTIAL PLAN
INTAKE STRUCTURE

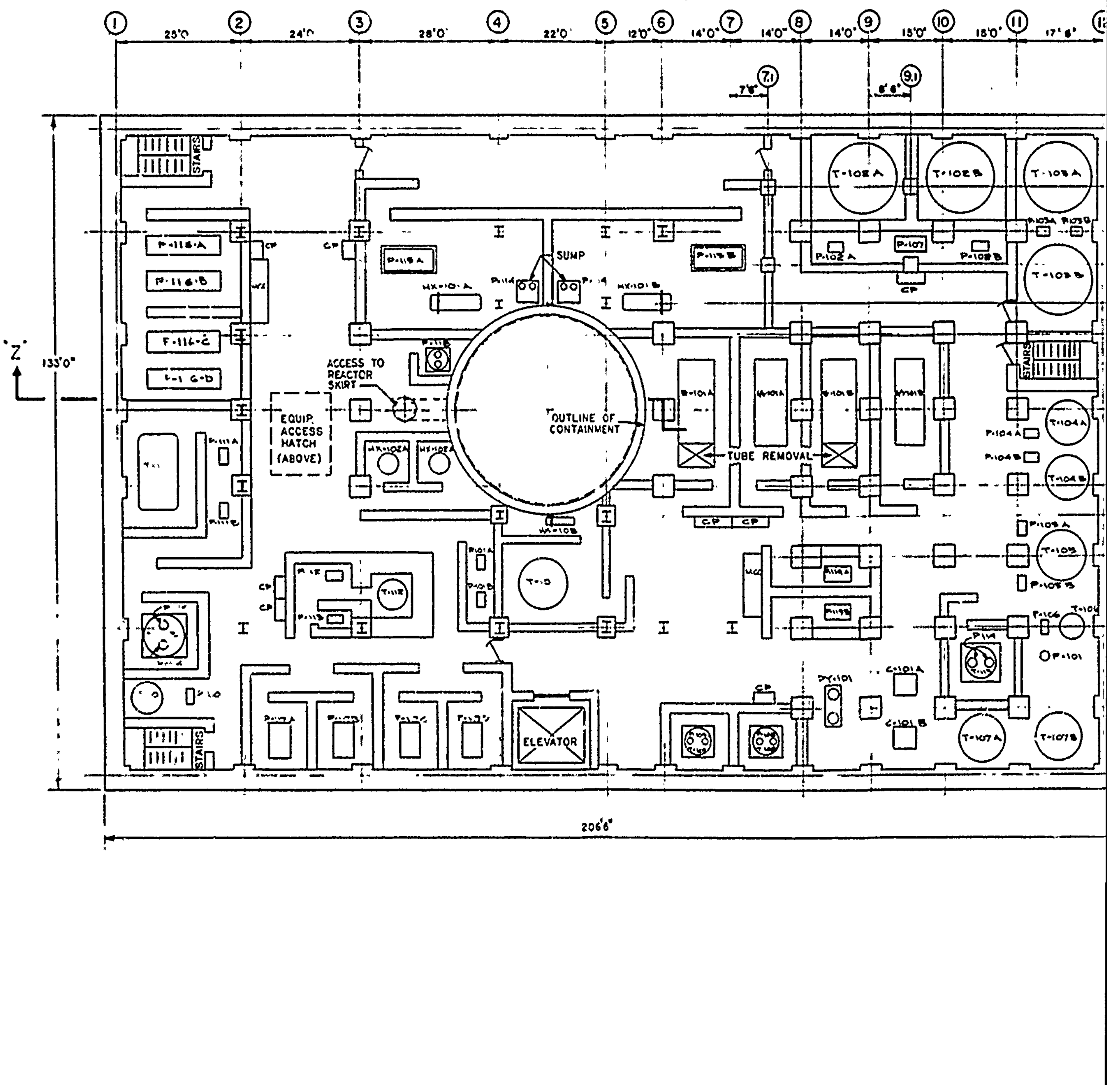
LEGEND:

1. REACTOR CONTAINMENT VESSEL
2. REACTOR SERVICE BUILDING
3. CONTROL BUILDING
4. DIESEL GENERATOR BUILDING
5. DIESEL FUEL OIL BUILDING
6. PROCESS / TURBINE BUILDING
7. PIPING TUNNEL
8. TURBINE SERVICE BUILDING
9. ADMINISTRATION BUILDING
10. BLOW-DOWN PIPE LINES
11. GATE HOUSE
12. MAKE-UP WATER PIPE
13. INTAKE STRUCTURE
14. ACCESS ROAD
15. AREA FOR CONSTRUCTION FACILITIES
16. FIRE PROTECTION WATER TANK
17. TREATED WATER STORAGE TANK
18. CHLORINATION EQUIPMENT
19. UNIT AUXILIARY TRANSFORMER
20. STEP-UP TRANSFORMER
21. CONDENSATE STORAGE TANK
22. PARKING AREA
23. DEMINERALIZED WATER STORAGE TANK
24. START-UP/STAND-BY TRANSFORMER
25. CONDENSER COOLING TOWER
26. SERVICE WATER COOLING TOWER & RESERVOIR
27. PROCESS STEAM LINE
28. TRANSMISSION LINES
29. BORATED WATER STORAGE TANK

PLOT PLAN
CNSG PLANT
FOR
DEPT. OF THE ARMY
RADFORD ARSENAL
RADFORD, VIRGINIA

DWG. 6390.002-D-001

2



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25'0"
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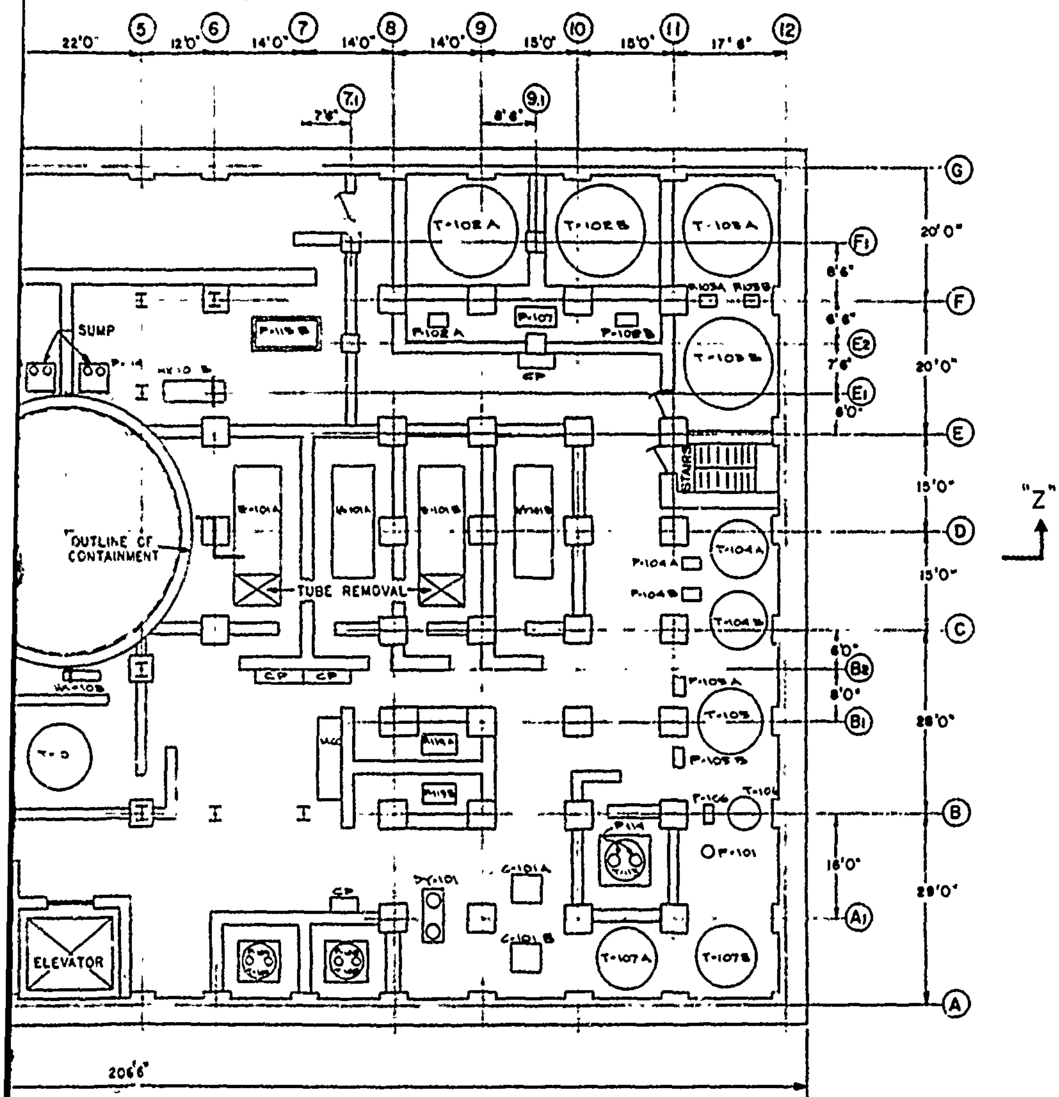
28'0"
22'0"
12'0"
14'0"
14'0"
14'0"
15'0"
18'0"
17'6"
7.1
9.1
7'6"
6'6"
"Z"
133'0"
206'6"
STAIRS
SUMP
ACCESS TO
REACTOR
SKIRT
EQUIP.
ACCESS
HATCH
(ABOVE)
OUTLINE OF
CONTAINMENT
TUBE REMOVAL
ELEVATOR
CP
T-102A
T-102B
T-103A
T-103B
P-107
P-102A
P-102B
P-116-A
P-116-B
P-104A
P-104B
T-104A
T-104B
T-105
T-107A
T-107B
C-101A
C-101B



LEGEND

C-101 NUCLEAR PLANT INSTRUMENT AIR COMPRESSOR
CP CONTROL PANEL
DY-101 NUCLEAR PLANT INSTRUMENT AIR DRYER
E-101 BORIC ACID RECOVERY EVAPORATOR
F-101 CASK DECONTAMINATION DRAIN COLLECTOR FILTER
GE-101 DEGASIFIER
HX-101 DECAY HEAT REMOVAL HEAT EXCHANGER
HX-102 LETDOWN COOLER
MCC MOTOR CONTROL CENTER
P-101 REACTOR COOLANT DRAIN TANK PUMP
P-102 REACTOR COOLANT BLEED EVAPORATOR FEED PUMP
P-103 REACTOR COOLANT DISTILLATE TRANSFER PUMP
P-104 EVAPORATOR DISTILLATE TEST TANK PUMP
P-105 PURIFICATION PUMP
P-106 CASK DECONTAMINATION DRAIN PUMP
P-107 REACTOR COOLANT BLEED RECIRCULATING PUMP
P-108 LOW ACTIVITY SUMP PUMP
P-109 HIGH ACTIVITY SUMP PUMP
P-110 LAUNDRY & HOT SHOWER TANK PUMP
P-111 DEMINERALIZER FLUSH PUMP
P-112 RESIN TRANSFER PUMP
P-113 SPENT RESIN SLUICE PUMP
P-114 EQUIPMENT & FLOOR DRAINS PUMP, SUMP
P-115 DECAY HEAT REMOVAL PUMP
P-116 EMERGENCY DECAY HEAT REMOVAL PUMP (AUX. FEEDWATER PUMP)
P-117 MAKEUP PUMP
P-118 COMPONENT SUMP PUMP
P-119 PRESSURIZER SPRAY PUMP
T-101 REACTOR COOLANT DRAIN TANK
T-102 REACTOR COOLANT BLEED HOLDUP TANK
T-103 REACTOR COOLANT DISTILLATE STORAGE TANK
T-104 EVAPORATOR DISTILLATE TEST TANK
T-105 SPENT FUEL POOL SURGE TANK
T-106 CASK DECONTAMINATION DRAIN COLLECTION TANK
T-107 NUCLEAR PLANT INSTRUMENT AIR RECEIVER
T-108 LOW ACTIVITY SUMP TANK
T-109 HIGH ACTIVITY SUMP TANK
T-110 LAUNDRY & HOT SHOWER DRAIN TANK
T-111 DEMINERALIZER FLUSH TANK
T-112 SPENT RESIN STORAGE TANK
T-113 EQUIPMENT & FLOOR DRAINS COLLECTION TANK

0 10 20 30 40
SCALE (FEET)

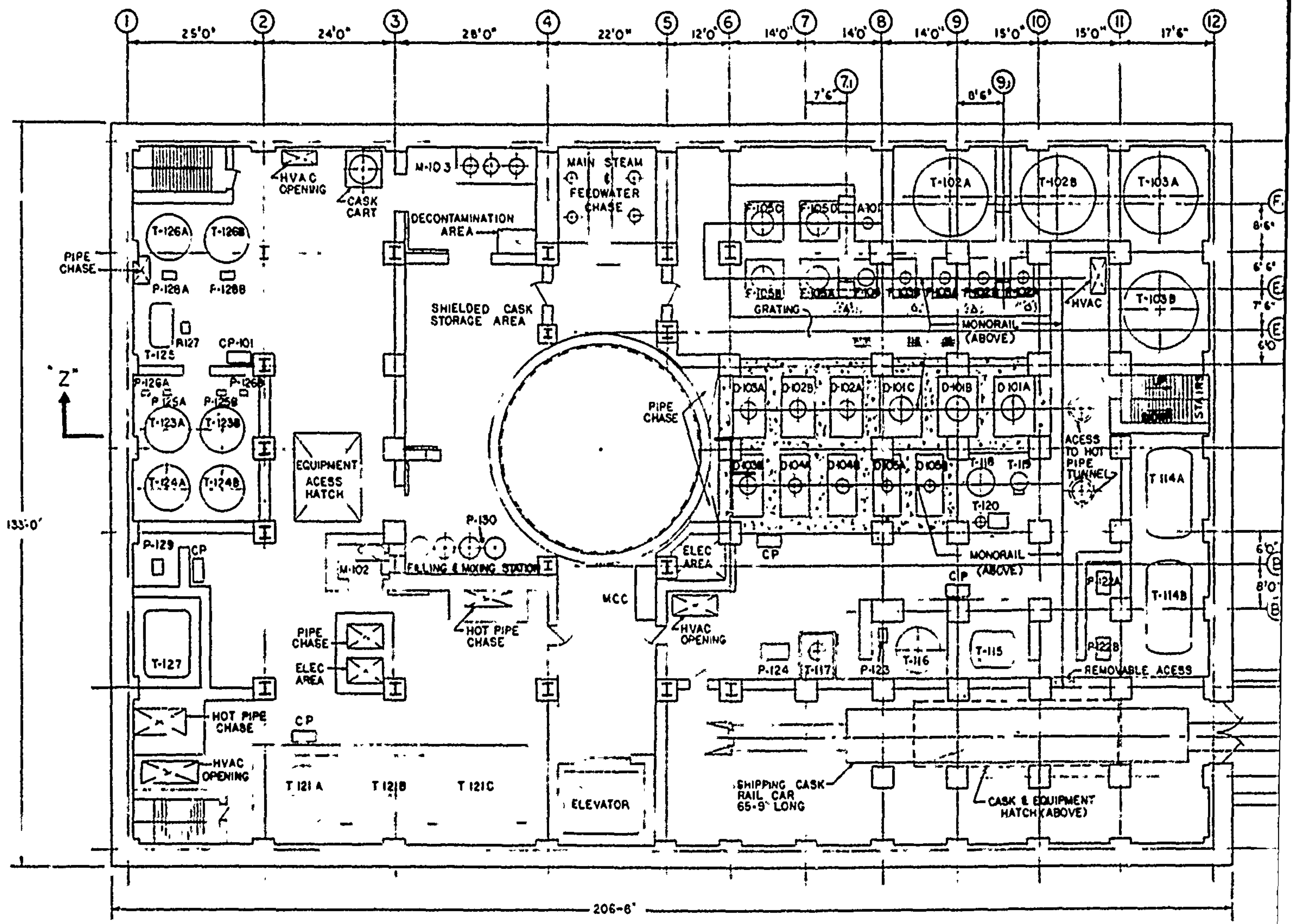
	3-9-75	FIRST ISSUE		
	DATE	DESCRIPTION		

REACTOR SERVICE BUILDING
GENERAL ARRANGEMENT
PLAN AT ELEVATION 0'-0"

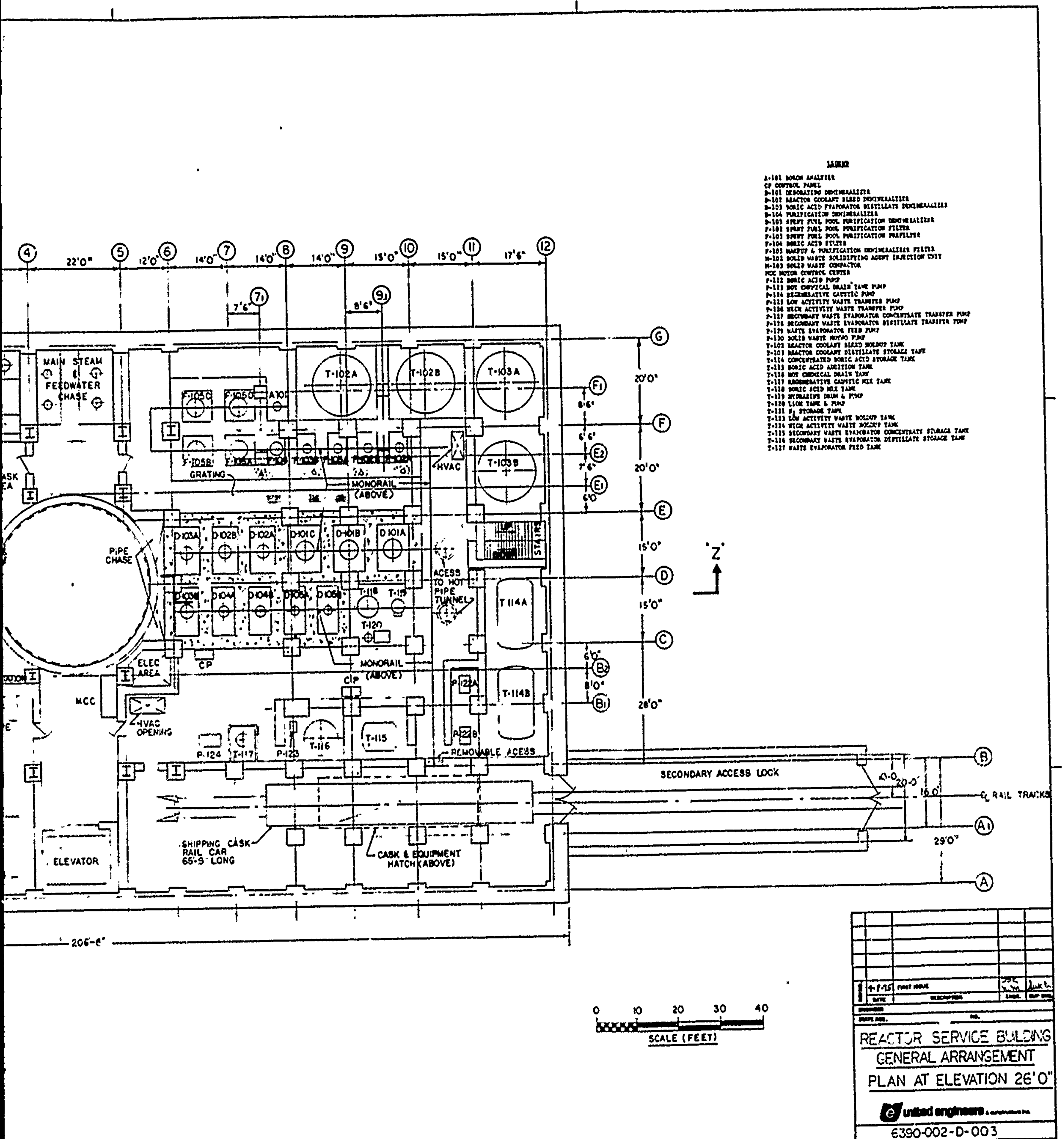
united engineers

6390-002-D-002

2



25'0"
24'0"
28'0"
22'0"
12'0"
14'0"
15'0"
17'6"
7'6"
8'6"
133'-0"
206'-6"
"Z"
HVAC OPENING
CASK CART
M-103
MAIN STEAM & FEEDWATER CHASE
DECONTAMINATION AREA
PIPE CHASE
T-126A
T-126B
P-126A
P-126B
SHIELDED CASK STORAGE AREA
T-125
R127
CP-101
T-123A
T-123B
T-124A
T-124B
P-125A
P-125B
EQUIPMENT ACESS HATCH
P-130
P-129
CP
M-102
FILLING & MIXING STATION
HOT PIPE CHASE
ELEC AREA
MCC
T-127
HOT PIPE CHASE
HVAC OPENING
T 121 A
T 121B
T 121C
ELEVATOR
T-102A
T-102B
T-103A
T-103B
F-105C
F-105D
A101
F-105B
F-105A
GRATING
MONORAIL (ABOVE)
HVAC
D-103A
D-102B
D-102A
D-101C
D-101B
D-101A
D-103B
D-104A
D-104B
D-105A
D-105B
T-118
T-119
T-120
ACESS TO HOT PIPE TUNNEL
STAIRS
T 114A
T-114B
P-122A
P-122B
REMOVABLE ACESS
P-124
T-117
P-123
T-116
T-115
SHIPPING CASK RAIL CAR 65-9" LONG
CASK & EQUIPMENT HATCH (ABOVE)



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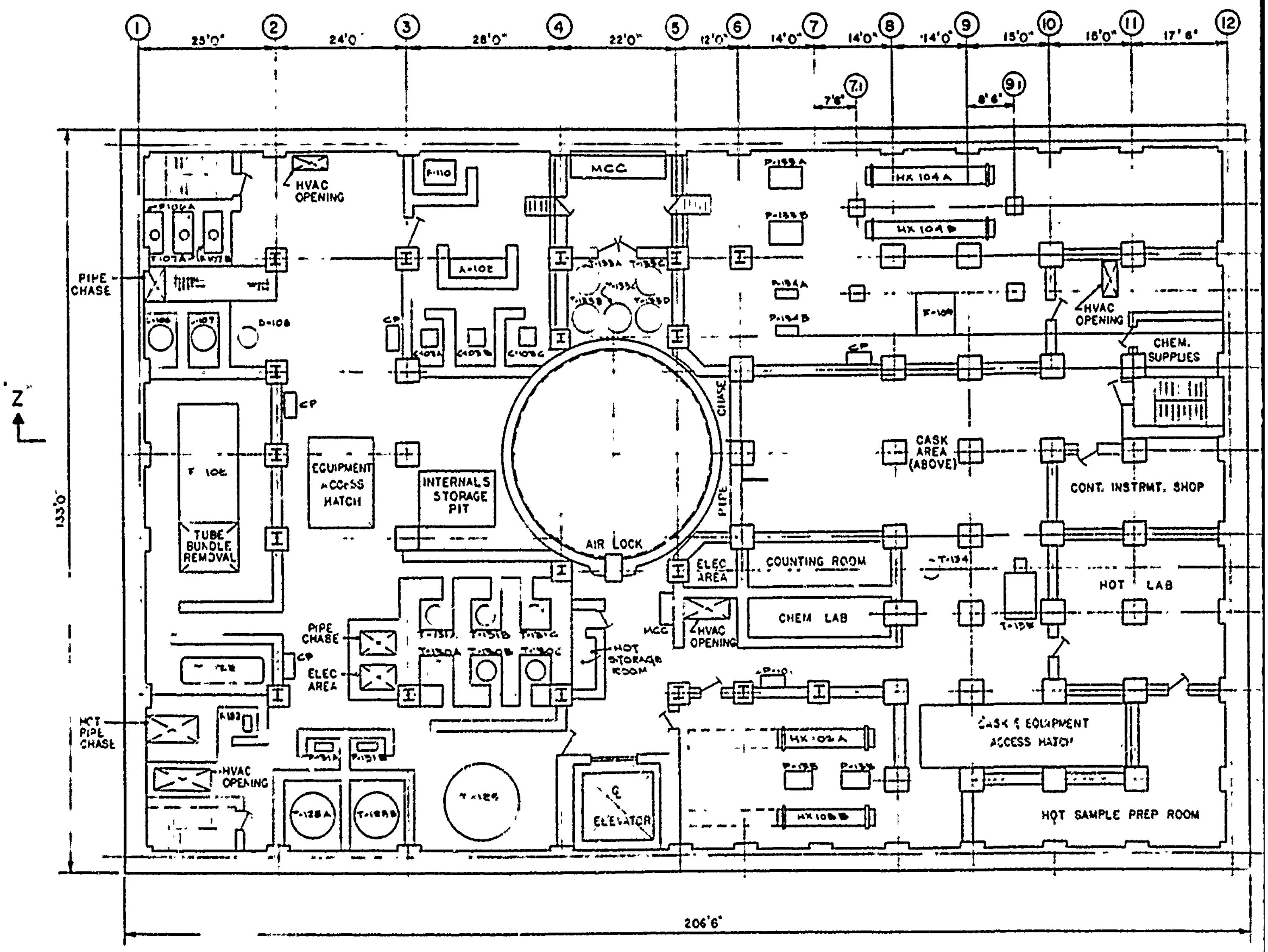
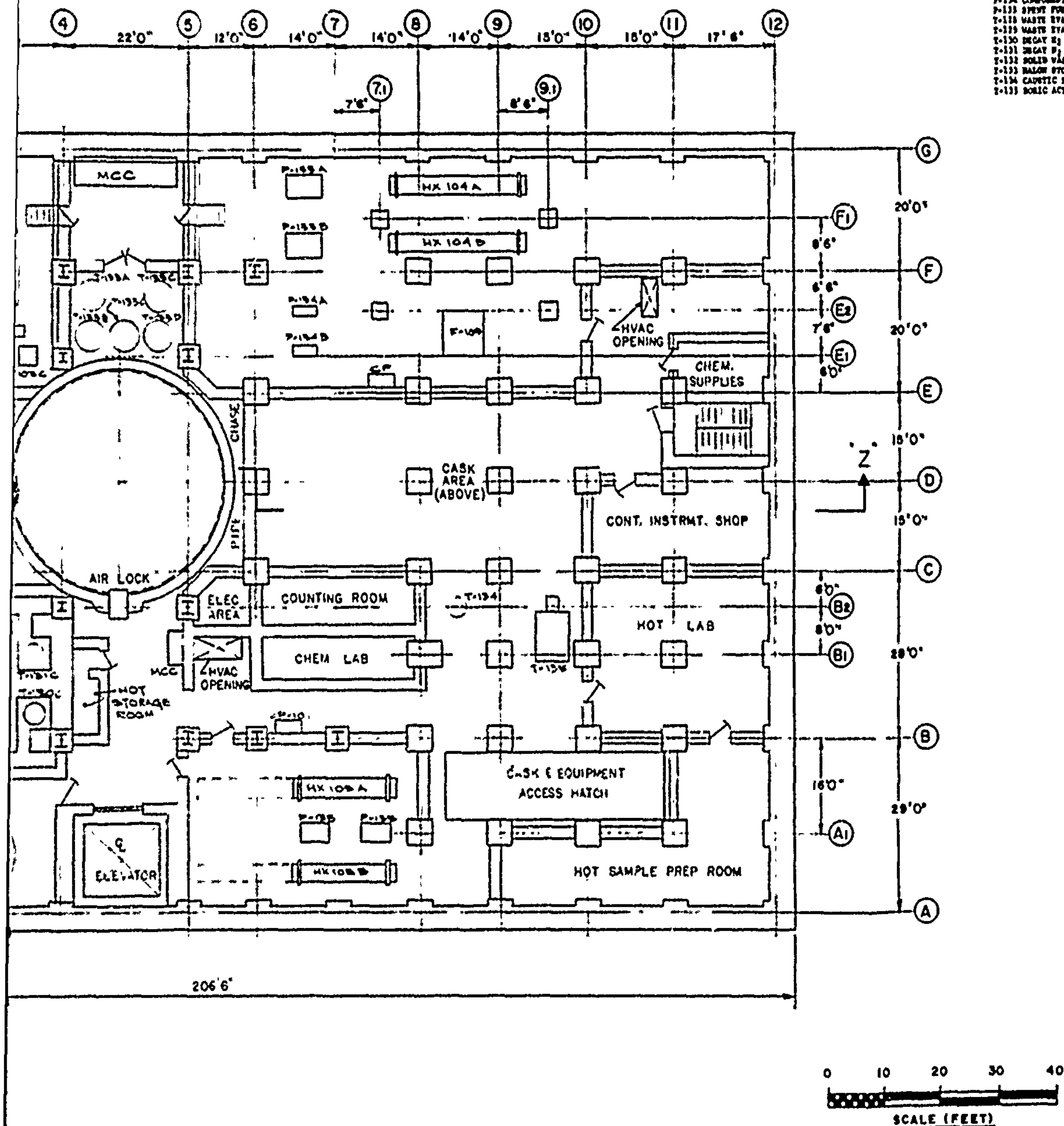

HVAC OPENING
PIPE CHASE
MCC
HX 104 A
HX 104 B
A-102
CP
D-108
F-109
HVAC OPENING
CHEM. SUPPLIES
CHASE
CASK AREA (ABOVE)
CONT. INSTRMT. SHOP
EQUIPMENT ACCESS HATCH
INTERNALS STORAGE PIT
TUBE BUNDLE REMOVAL
AIR LOCK
ELEC AREA
COUNTING ROOM
HOT LAB
CHEM LAB
HVAC OPENING
PIPE CHASE
ELEC AREA
HOT STORAGE ROOM
HOT PIPE CHASE
HVAC OPENING
CASK & EQUIPMENT ACCESS HATCH
HX 102 A
HX 102 B
ELEVATOR
HOT SAMPLE PREP ROOM
PIPE
133'0"
206'6"
Z



LEGEND

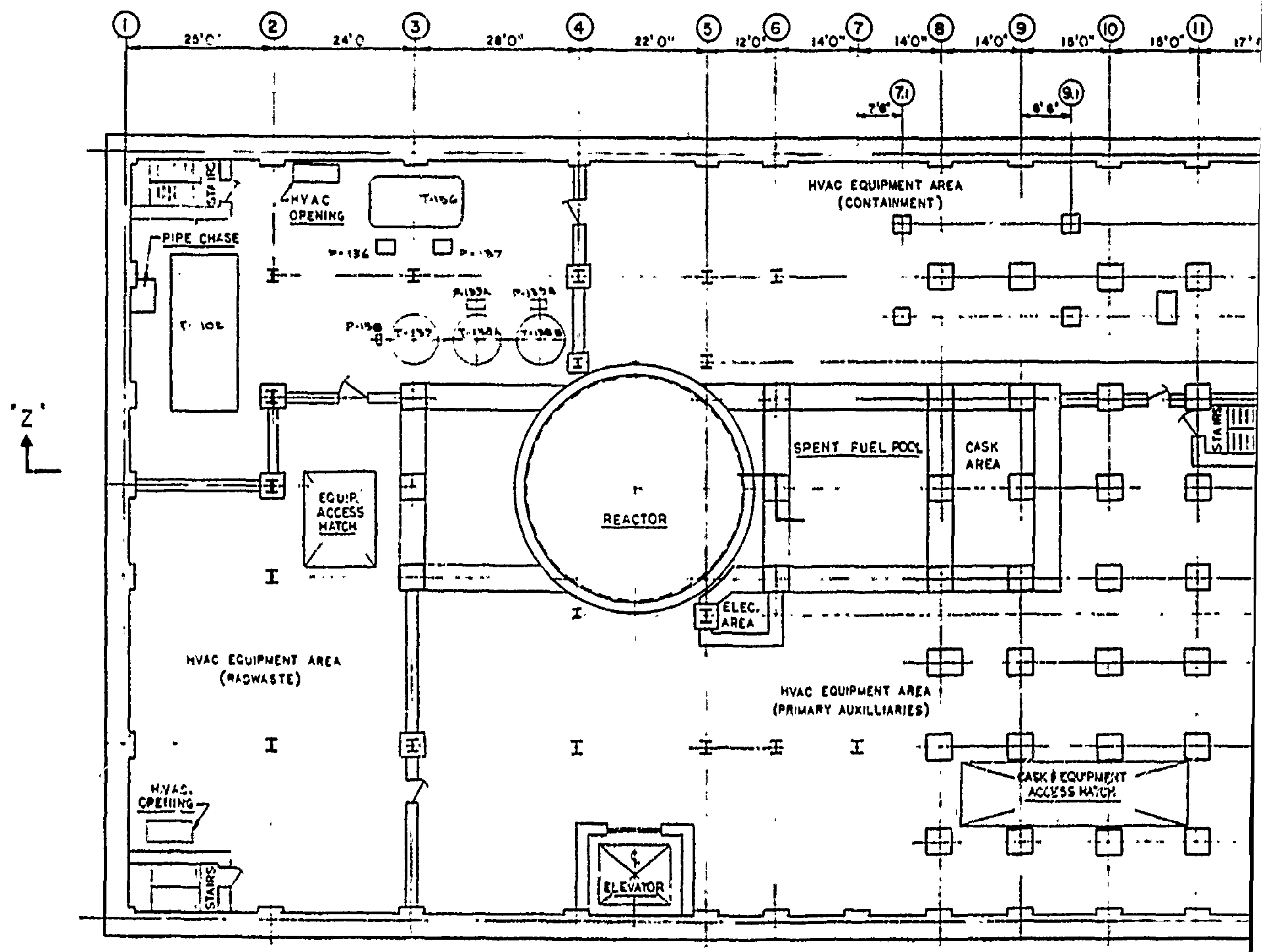
A-102 WASTE GAS ANALYZER
C-103 GAS WASTE COMPRESSOR
CP CONTROL PANEL
D-106 LIQUID WASTE DEMINERALIZER
D-107 WASTE EVAPORATOR DISTILLATE DEMINERALIZER
D-108 SECONDARY EVAPORATOR DISTILLATE DEMINERALIZER
E-102 EVAPORATOR WASTE UNIT
F-106 LIQUID WASTE FILTER
F-107 WASTE EVAPORATOR FEED FILTER
F-109 COMPONENT COOLING ELECTROMAGNETIC FILTER
F-110 WASTE GAS FILTER
HX-104 COMPONENT COOLING HEAT EXCHANGER
HX-105 SPENT FUEL POOL COOLING HEAT EXCHANGER
P-131 WASTE EVAPORATOR DISTILLATE TRANSFER PUMP
P-132 SOLID WASTE EVAPORATOR CONCENTRATE TRANSFER PUMP
P-133 COMPONENT COOLING WATER PUMP
P-134 COMPONENT COOLING WATER BOOSTER PUMP
P-135 SPENT FUEL POOL COOLING HEAT EXCHANGER PUMP
T-128 WASTE EVAPORATOR DISTILLATE TEST TANK
T-129 WASTE EVAPORATOR DISTILLATE STORAGE TANK
T-130 DECAY H_2 TANK
T-131 DECAY H_2 TANK
T-132 SOLID WASTE EVAPORATOR CONCENTRATE STORAGE TANK
T-133 HALON STORAGE TANK
T-134 CAUSTIC STORAGE TANK
T-135 BORIC ACID BIN & SCREW CONVEYOR

4-8-75	FIRST ISSUE			
DATE	DESCRIPTION			

REACTOR SERVICE BUILDING
GENERAL ARRANGEMENT
PLAN AT ELEVATION 46'-0"

united engineers

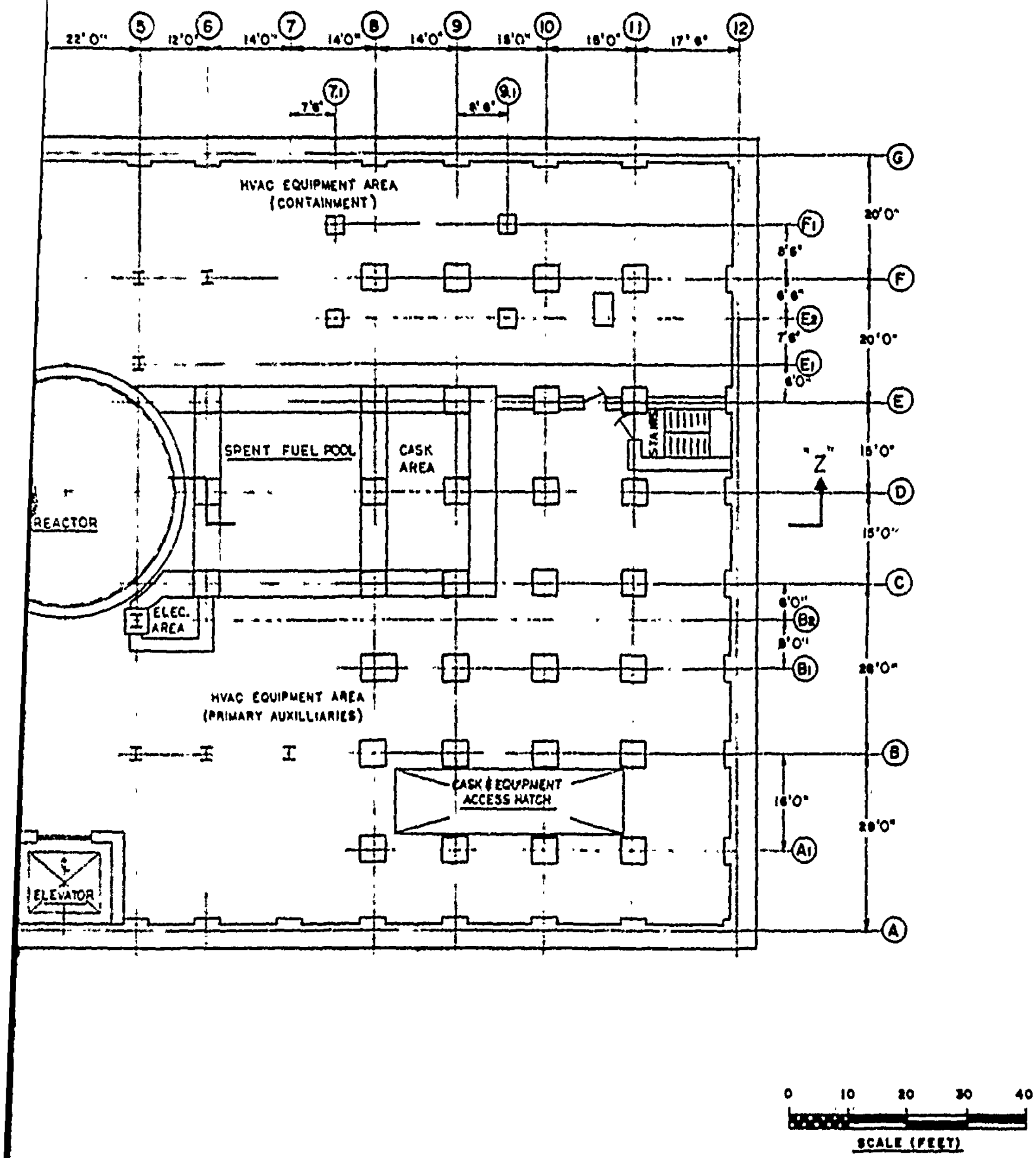
6390-002-D-004



25'0"
24'0
28'0"
22'0"
12'0"
14'0"
14'0"
14'0"
18'0"
18'0"
7'6"
8'6"
HVAC EQUIPMENT AREA
(CONTAINMENT)
HVAC
OPENING
T-156
PIPE CHASE
P-136
P-137
T-102
P-139A
P-139B
P-138
T-137
T-138A
T-138B
'Z'
SPENT FUEL POOL
CASK
AREA
STAIRS
EQUIP.
ACCESS
HATCH
REACTOR
ELEC.
AREA
HVAC EQUIPMENT AREA
(RADWASTE)
HVAC EQUIPMENT AREA
(PRIMARY AUXILIARIES)
CASK & EQUIPMENT
ACCESS HATCH
H.V.A.C.
OPENING
STAIRS
ELEVATOR

LEGEND

E-103 SECONDARY WASTE EVAPORATOR UNIT
P-136 MIX TANK TRANSFER PUMP
P-137 MIXING PUMP
P-138 SECONDARY EVAPORATOR FEED PUMP
P-139 [illegible] SOLUTION STORAGE TANK PUMP
T-134 MIXING & NEUTRALIZATION TANK
T-137 SECONDARY WASTE EVAPORATOR FEED TANK
T-136 [illegible] SOLUTION STORAGE TANK



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	DATE	DESCRIPTION	ENGR.	SUP. ENG.

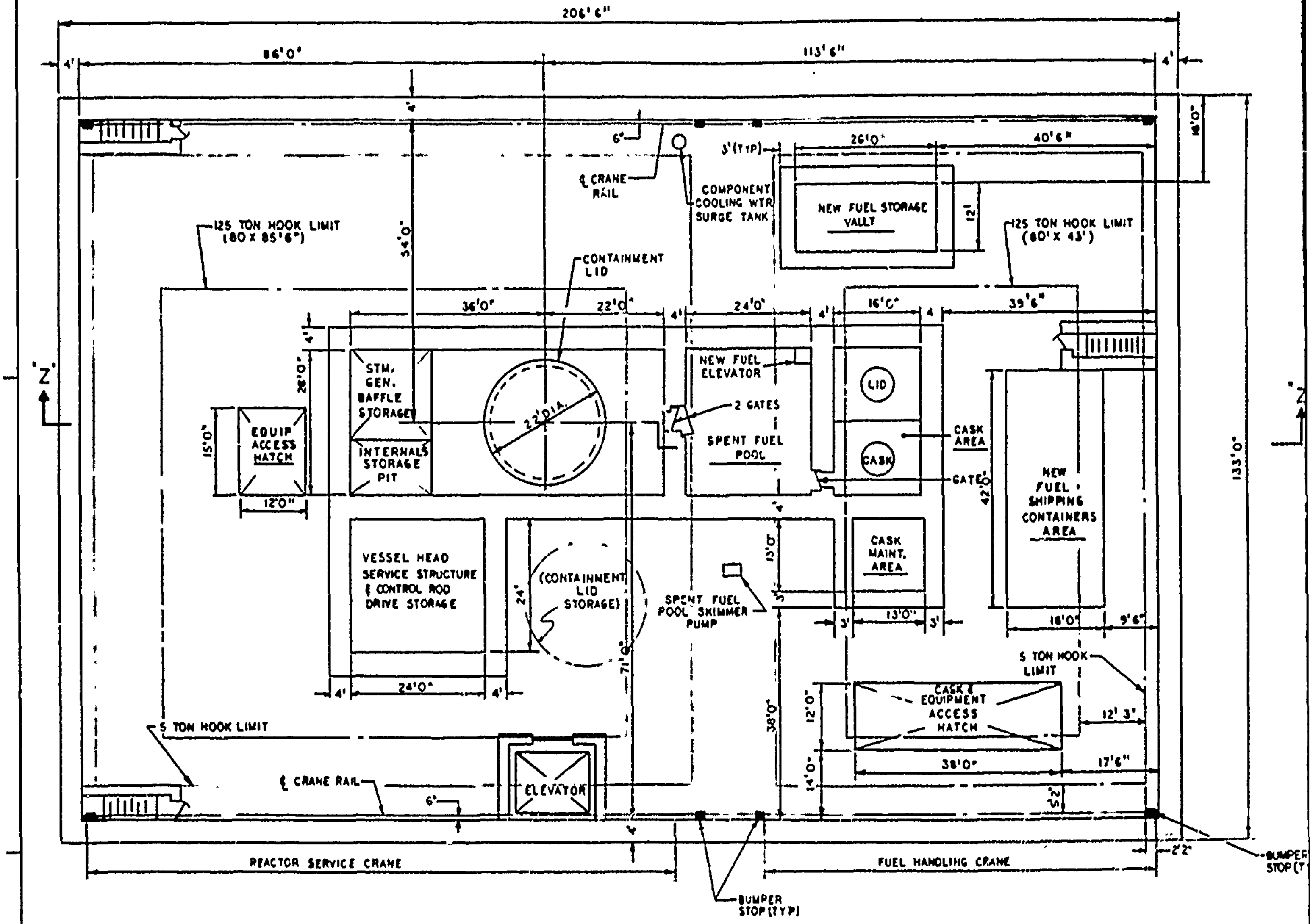
REACTOR SERVICE BUILDING

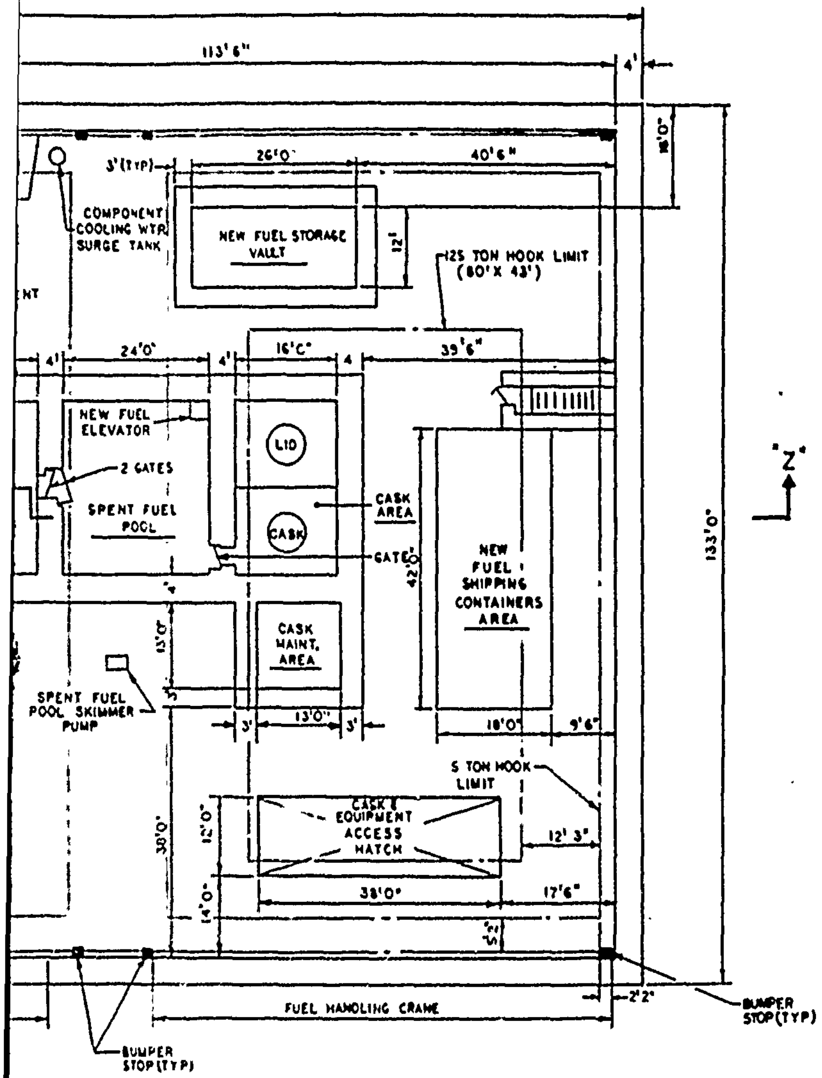
GENERAL ARRANGEMENT

PLAN AT ELEVATION 66'0"

United Engineers

6390-002-D-005


206'6"
86'0"
113'6"
4'
4'
16'0"
6"
3'(TYP)
26'0"
40'6"
℄ CRANE RAIL
COMPONENT COOLING WTR SURGE TANK
NEW FUEL STORAGE VAULT
12'
125 TON HOOK LIMIT (80 X 85'6")
125 TON HOOK LIMIT (60' X 43')
54'0"
CONTAINMENT LID
36'0"
22'0"
24'0"
16'0"
39'6"
'Z'
STM. GEN. BAFFLE STORAGE
28'0"
NEW FUEL ELEVATOR
LID
15'0"
EQUIP ACCESS HATCH
22'DIA.
2 GATES
SPENT FUEL POOL
CASK AREA
INTERNALS STORAGE PIT
CASK
GATE
NEW FUEL SHIPPING CONTAINERS AREA
133'0"
42'0"
12'0"
VESSEL HEAD SERVICE STRUCTURE ℄ CONTROL ROD DRIVE STORAGE
(CONTAINMENT LID STORAGE)
13'0"
CASK MAINT. AREA
24'
SPENT FUEL POOL SKIMMER PUMP
13'0"
18'0"
9'6"
71'0"
5 TON HOOK LIMIT
24'0"
CASK & EQUIPMENT ACCESS HATCH
5 TON HOOK LIMIT
38'0"
12'0"
12'3"
℄ CRANE RAIL
ELEVATOR
38'0"
17'6"
14'0"
6"
2'2"
BUMPER STOP(TYP)
REACTOR SERVICE CRANE
FUEL HANDLING CRANE
BUMPER STOP(TYP)



0 5 10 20 30

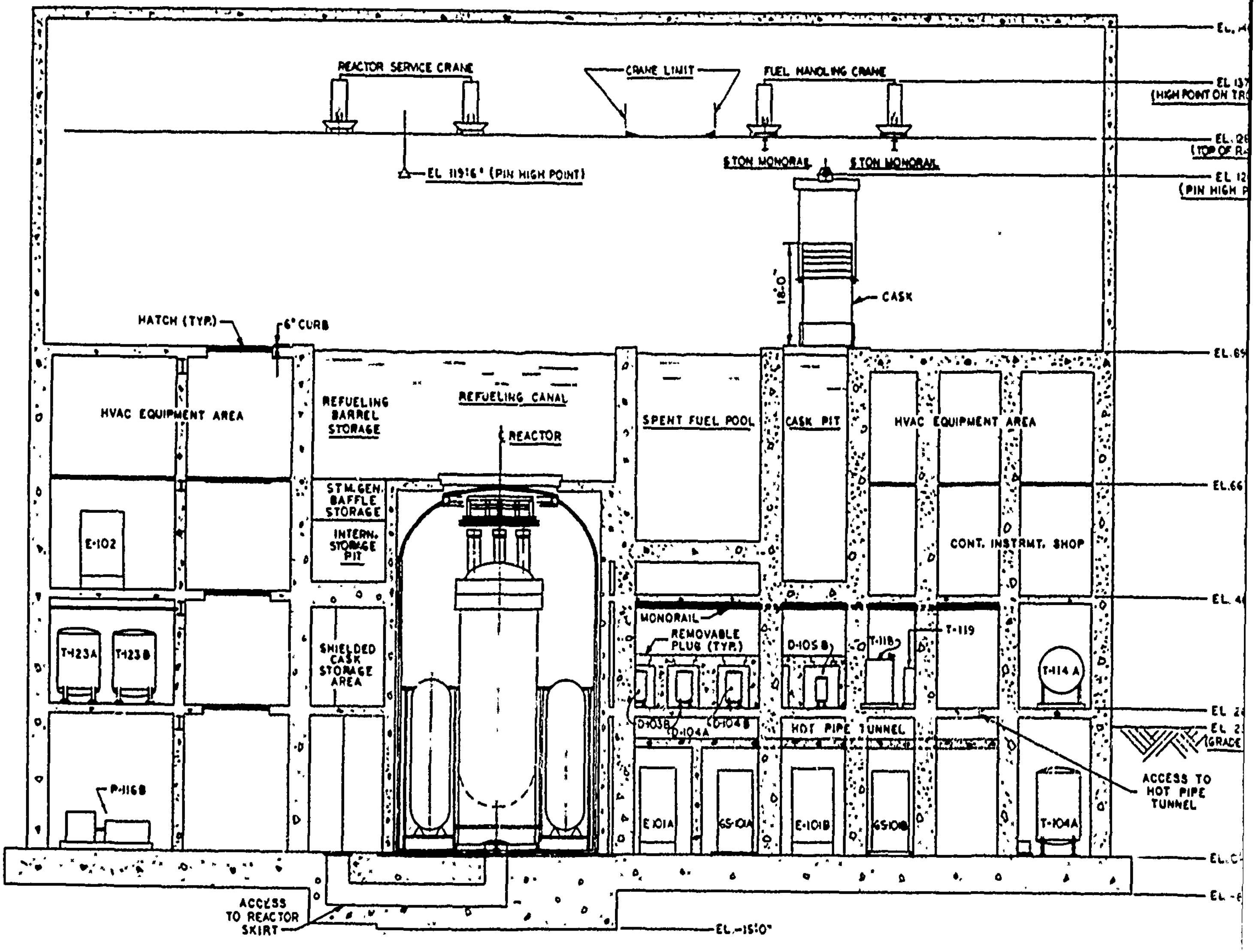
SCALE (FT)

REACTOR SERVICE BUILDING
GENERAL ARRANGEMENT
PLAN AT ELEVATION 89'0
OPERATING FLOOR

united engineers

6390-002-D-006

2


REACTOR SERVICE CRANE
CRANE LIMIT
FUEL HANDLING CRANE
EL 11'6" (PIN HIGH POINT)
5 TON MONORAIL
5 TON MONORAIL
CASK
16'-0"
HATCH (TYP.)
6" CURB
HVAC EQUIPMENT AREA
REFUELING BARREL STORAGE
REFUELING CANAL
REACTOR
SPENT FUEL POOL
CASK PIT
HVAC EQUIPMENT AREA
STM. GEN. BAFFLE STORAGE
INTERN. STORAGE PIT
E-102
CONT. INSTRMT. SHOP
T-123A
T-123B
SHIELDED CASK STORAGE AREA
MONORAIL
REMOVABLE PLUG (TYP.)
D-105 B
T-118
T-119
T-114 A
D-103B
D-104A
D-104 B
HOT PIPE TUNNEL
ACCESS TO HOT PIPE TUNNEL
P-116B
E-101A
GS-101A
E-101B
GS-101B
T-104A
ACCESS TO REACTOR SKIRT
EL.-15'0"
(HIGH POINT ON TR
(TOP OF R
(PIN HIGH P
GRADE

SECTION "Z-Z"

LEGEND

D-103 BORIC ACID EVAPORATOR DISTILLATE DEMINERALIZER

D-104 PURIFICATION DEMINERALIZER

D-105 SPENT FUEL POOL PURIFICATION DEMINERALIZER

E-101 BORIC ACID RECOVERY EVAPORATOR

E-102 EVAPORATOR WASTE UNIT

P-116B EMERGENCY DELAY HEAT REMOVAL PUMP

T-104 EVAPORATOR DISTILLATE TEST TANK

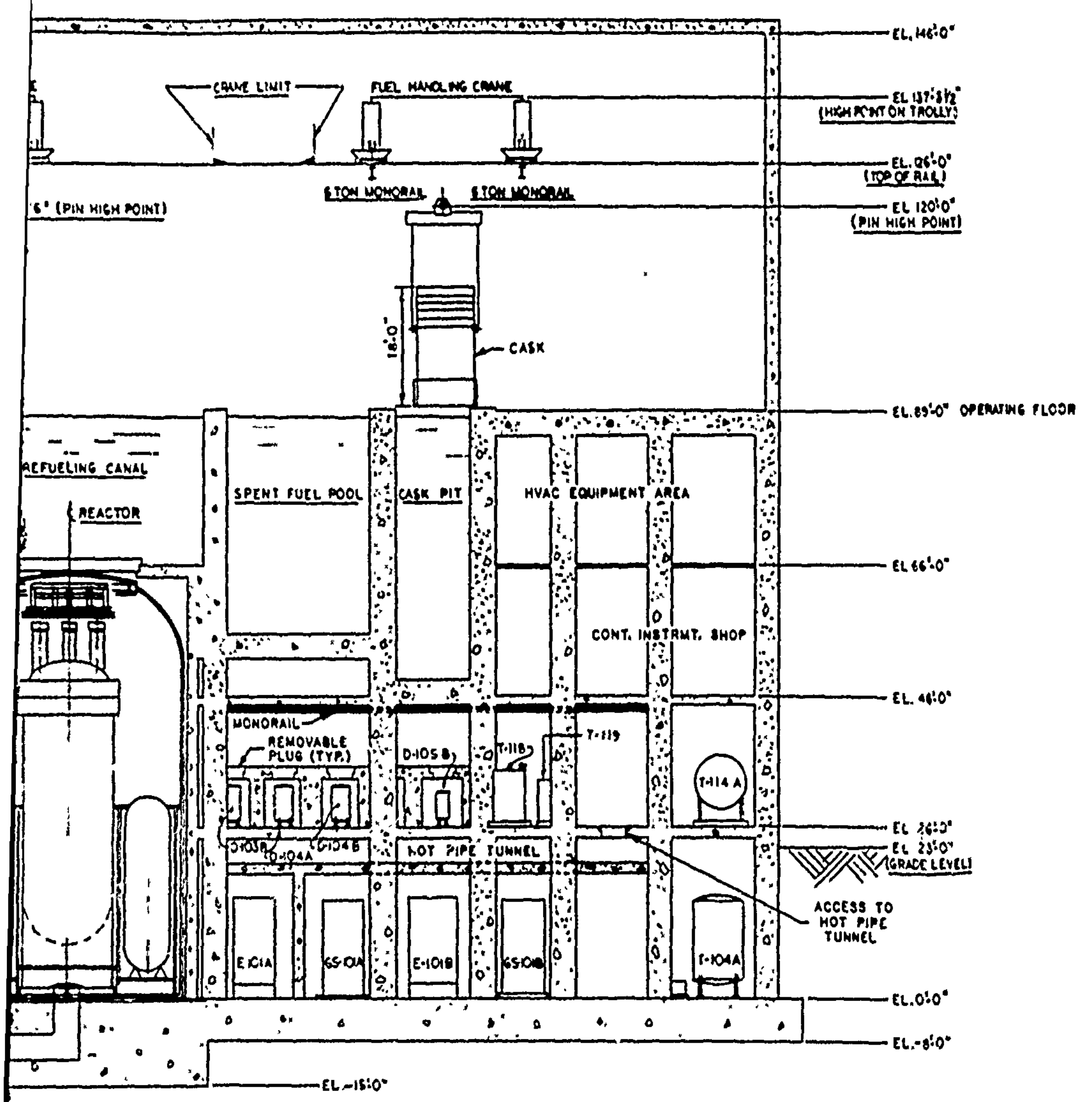
T-114 CONCENTRATED BORIC ACID STORAGE TANK

T-118 BORIC ACID MIX TANK

T-119 HYDRAZINE DRUM

T-133 LOW ACTIVITY WASTE HOLDUP TANK

GS-101 GAS STRIPPER



SECTION "Z-Z"

0 10 20 30 40

SCALE (FEET)

9-1-75	FIRST ISSUE		
DATE	DESCRIPTION		

REACTOR SERVICE BUILDING

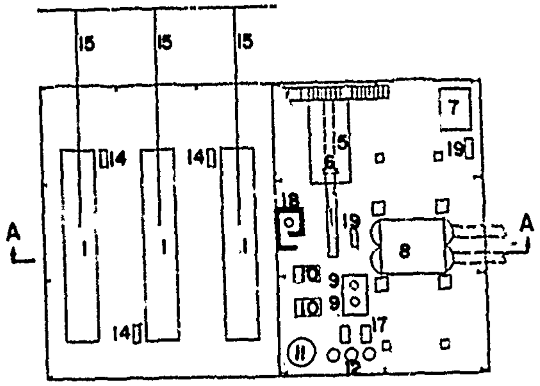
GENERAL ARRANGEMENT

ELEVATION-SECTION VIEW

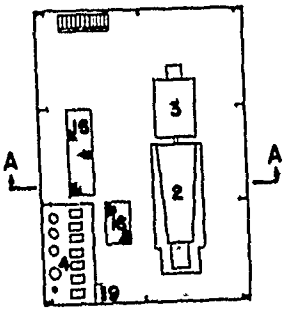
united engineers

6390-002-D-007

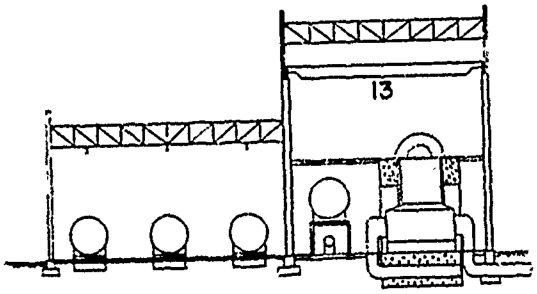
2



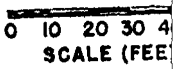
GROUND FLOOR
PLAN ELEV. 0'-0"

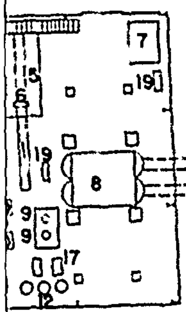


OPERATING FLOOR
PLAN ELEV. 23'-0"

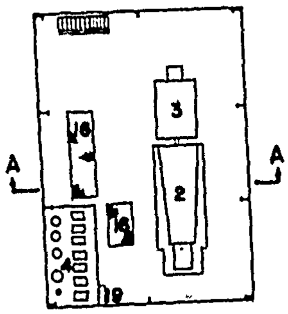


SECTION A-A





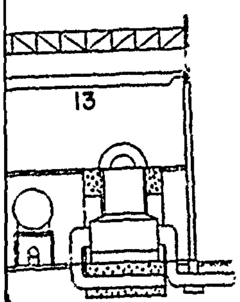
LOOR
V. 0'-0"



OPERATING FLOOR
PLAN ELEV. 23'-0"

LEGEND:

1. EVAPORATOR
2. TURBINE
3. GENERATOR
4. CHEMICAL FEED AREA
5. DRAIN RESERVOIR
6. FEEDWATER HEATER
7. TURBINE LUBE OIL SYSTEM
8. CONDENSER
9. CONDENSATE PUMP
10. FEEDWATER PUMP
11. DEAERATOR HEATER TANK
12. CONDENSATE DEMINERALIZERS
13. TURBINE BRIDGE CRANE
14. BLOWDOWN COOLER
15. EVAPORATOR MONORAIL
16. GRATING AREA
17. CONDENSATE BOOSTER PUMP
18. PROCESS FEED WATER FILTER
19. MCC



A - A

0 10 20 30 40 50
SCALE (FEET)

PROCESS/TURBINE BLDG.
CNSG PLANT
FOR
DEPT. OF THE ARMY
RADFORD ARSENAL
RADFORD, VIRGINIA
UNITED ENGINEERS & CONSTR. INC.
DWG. 6390-002-D-008

SECTION 4.0 ECONOMIC AND OPTIMAL SYSTEM EVALUATION

4.1 Introduction

This section deals with the economic evaluation of a system with a nuclear plant* vs. alternate systems for meeting energy requirements of RAAP. Also included is an analysis for determining an optimum mix for the nuclear plant. The evaluation is complex because of many diverse considerations needed to accurately reflect the economics of using a standard nuclear reactor in an existing system with dual requirements of steam and electricity. Factors such as the existing system design, how the nuclear reactor fits into the overall system, system reliability, load variations over the year, optimal way of system operation and existence of many alternatives for meeting electrical requirements are significant and have to be reflected in the evaluation. Furthermore, capital, fuel and O&M costs for various units in the system must also be taken into account. The model used in this evaluation tries to incorporate all significant aspects either conceptually or analytically or by a combination of both. Where significant deficiencies exist, an attempt is made to point them out so as to aid the decision maker's comprehension of the uncertainties involved.

4.2 Criteria For Economic Evaluation

RAAP's peak requirements at full mobilization are 1,070,000 #/hr of steam and 65.1 MWe of electricity. Unique features of the plant are that part of the steam requirements are for 40 PSI steam, there are existing boilers and turbines with steam requirements at certain specific conditions and that all or part of the electrical requirements can be met by buying electricity from Appalachian Power. On the other hand, the PE-CNSG is a fixed design capacity machine and provides flexibility only upto a limited extent.

*Specifically the PE-CNSG as discussed in Section 3.

Thus, for any economic evaluation of the PE-CNSG compared to conventional sources, it is extremely important to take into consideration how well the PE-CNSG fits into the Radford system. A one to one evaluation of the PE-CNSG with conventional sources will, therefore, be meaningless for RAAP because such an evaluation cannot reflect the particular characteristics of RAAP. Based upon the above considerations, a total systems approach is used to evaluate the economics of the PE-CNSG vs conventional systems. Total costs of meeting process and other steam and electrical requirements of RAAP are found for a "system with nuclear plant" and compared to an "All conventional system". All significant costs which can vary for the two systems are incorporated in the evaluation. This approach, therefore, reflects the true economics of the PE-CNSG for RAAP.

Another important consideration is the actual level of operation of the Radford plant for the period of evaluation (1985 to 2000). This is important because it determines the extent to which the nuclear plant can be utilized. A higher actual level of operation will mean a fuller utilization of the nuclear plant and thus more benefits from the nuclear plant in terms of fuel cost savings. On the other hand, it might be unrealistic to expect RAAP to operate at full mobilization for the entire period of evaluation. This will require assumptions which might have a small probability of becoming reality. Based upon discussions with DOD personnel, the expected average utilization of RAAP over the evaluation period is taken as 45% of peak full mobilization requirements. This is the base case for evaluating operating economics of the system(s) under consideration.

As far as the steam export capacity of the system with nuclear plant is concerned, the total installed export capacity should be at least equal to full mobilization steam requirements. Reliability considerations are, however, based upon providing reliability equivalent to that of an all conventional system.

In summary the following criteria will be used for economic evaluation:

(i) Economic evaluation of nuclear vs conventional sources will be based upon comparing total cost of meeting steam and electrical requirements of RAAP by a "system with nuclear plant" vs an "All conventional system", e.g. not comparing only the PE-CNSG vs a corresponding coal plant alone but a system of PE-CNSG and coal, vs a total coal system.

(ii) The operating economics of the two systems will be based upon RAAP's expected usage for the period under evaluation.

(iii) The overall system steam export capacity will be at least equal to full mobilization steam requirements. Reliability considerations for the "system with nuclear plant" will be such as to have an overall reliability comparable to that of an "All conventional system".

It should be noted that Criteria (ii) above requires operating economics to be based upon expected usage. The criteria generally used by DOD is full mobilization usage. Expected usage, however, does not exclude full mobilization usage. If RAAP is expected to operate at full mobilization for the entire evaluation period, expected usage will be the same as full mobilization usage. A part of this section also deals with economics based upon full mobilization usage over the entire evaluation period.

4.3 Method Of Economic Evaluation

The economic evaluation is based upon comparing total owning and operating costs for a system with nuclear plant to that of an all conventional system. It is assumed that all new facilities go into operation in 1985. The following are the cost categories which go into the evaluation.

(i) Capital Costs

Capital costs for a system with nuclear plant or an all conventional system are the capital costs associated with installation of additional facilities under the particular system. In the case of a system with nuclear plant, the costs consist of the capital costs of the nuclear plant, the steam distribution system to the main headers, electrical transmission lines from the nuclear plant to the main plant area and the back up boiler. Capital costs such as those associated with rehabilitation of the existing power house boiler are ignored because these costs are common to both the system with nuclear plant and all conventional systems.

Base costs were estimated for the base date, April 1976. Escalation was applied on total base costs from base date to mid point of construction period. Interest during construction was applied on the total escalated cost from mid point of construction period to the date of operation. Both escalation and interest during construction are compounded annually. It is clear that the particular cash flow curve for the nuclear or boiler plants was not considered. However, experience with large plants has

shown that the above approach is an excellent approximation to finding final capital costs. In this particular case, the construction periods are much smaller than that for large plants and the above approach should give almost as accurate results as the one using detailed cash flow curves.

Contingency was applied on total costs including base costs, escalation and interest during construction. This is equivalent to applying contingency to base costs and then treating contingency as part of base costs for estimating escalation and interest during construction.

(ii) Annual Operating Costs

These costs consist of fuel and O&M costs and the cost of buying electricity from Appalachian Power to meet the expected steam and electrical requirements of RAAP. More specifically, for a system with nuclear plant, these costs consist of nuclear fuel costs for producing steam and electricity, boiler fuel costs for meeting remainder of the steam requirements and for any electricity produced, O&M costs associated with the operation of nuclear as well as boiler plants and the cost of buying electricity from Appalachian Power to meet total requirements. Due consideration is given to auxiliary power requirements as well as electricity available from the operation of extraction turbines in the existing power house. The reference date for annual operating costs is January 1985 when all new facilities are assumed to go into operation.

(iii) Working Capital Costs

Working capital is defined as current assets less current liabilities. Current assets consist of cash, inventory, etc. Current liabilities consists of salaries payable, bills payable etc. Thus, the working capital (excluding that for fuel) is the average net cash required for system operation plus the value of ..nventory of materials and supplies. As such working capital is a non-depreciating asset. The cost of working capital is, therefore, the interest charges associated with maintaining the working capital. The cost of working capital (excluding fuel) is believed to be small for either the system with nuclear plant or the all conventional system. On a comparative basis, the cost of working capital is expected to have practically no effect on the results of this study and is, therefore, not incorporated in the analysis.

There is no working capital associated with nuclear fuel. This is because payments are made after the fuel has been used. The cost of working capital associated with conventional fuels is ignored in the analysis. This can have some effect on the results in favor of all conventional system. The effect, however, should only be minor as far as overall results are concerned.

(iv) Total Present Worth Owning and Operating Costs

This is the total cost associated with the owning and operating of system with nuclear plant or all conventional system to meet expected steam and electrical requirements of the Radford plant. Once again, common cost items such as those associated with

rehabilitation of existing power house boilers are ignored and thus total owning and operating costs are only comparative.

To arrive at present worth owning and operating costs, the annual operating costs are multiplied by a present worth factor and the resultant then added to capital costs. As mentioned before, annual operating costs are estimated for the beginning of first year of operation; however, these costs will not remain constant over the life of the plant but will increase progressively due to the effects of inflation. Thus, an inflation adjusted present worth factor is used which, if multiplied to the annual operating costs corresponding to date of operation, will give the present worth (corresponding to date of operation) of annual operating costs, including effects of inflation, over the evaluation period.

To derive the formula for inflation adjusted present worth factor, let

A = Annual operating costs for date of operation

e = Constant annual escalation rate per year (for annual operating costs) over the evaluation period

i = Cost of capital per year

n = Evaluation period, years

Then the actual operating costs over the life of the plant are as shown below:

Year of operation	1	2	3	4	---n
Actual operating Costs	A	$A(1 + e)$	$A(1 + e)^2$	$A(1 + e)^3$	----$A(1 + e)^{n-1}$

The present worth (corresponding to date of operation) of annual operating costs is:

$$= A + \frac{A(1 + e)}{(1 + i)} + \frac{A(1 + e)^2}{(1 + i)^2} + \frac{A(1 + e)^3}{(1 + i)^3} + --- + \frac{A(1 + e)^{n-1}}{(1 + i)^{n-1}}$$

This is a geometric series and the summation (for $i \neq e$) is:

$$= A \; \frac{1-\left(\frac{1 + e}{1 + i}\right)^n}{1-\left(\frac{1 + e}{1 + i}\right)} \qquad = A \, \frac{1 + i}{i - e} \left[1- \left(\frac{1 + e}{1 + i}\right)^n \right]$$

When $i = e$, the series becomes:

$= A + A + A +$ --- to n terms

$= 40\ A$

Thus by definition, the inflation adjusted present worth factor is:

$$= \begin{cases} \frac{1 + i}{i - e} \left[1-\left(\frac{1 + e}{1 + i}\right)^n \right] & \text{when } i \neq e \\ n & \text{when } i = e \end{cases}$$

It should be noted that the derivation of the factor is based upon assuming constant escalation and interest rates for the entire evaluation period.

Based upon the above derivation we find:

Total Present Worth Owning & Operating Costs

= (Total capital investment) + (Annual operating costs) x

(Inflation adjusted PWF)

4.4 Data Base Set for Evaluation

The economic evaluation needs a multitude of data such as economic factors, plant factors, cost data, energy requirements otc. Some of this data is subject to significant uncertainty. Because of this, a base set of data is developed and is shown in Table 4.1 and Figures 4.1 and 4.2. This base set represents the best single point estimates for various factors which go into the evaluation. Unless otherwise stated, the economic evaluation is based upon this base set of data. Some of the data given in the base set are discussed below.

Steam Conditions

At present, RAAP uses steam conditions of 450 PSI, 750°F (294°SH) at the main distribution header in the main plant area. The conditions of secondary steam from the PE-CNSG make it impossible for the nuclear plant to export steam at these conditions. However, it is understood that most process requirements are for saturated steam at 100 PSI or less. This suggests that the existing distribution system is inefficient and can be revamped so that 400 PSI, saturated steam conditions at the main plant distribution header are acceptable to meet process requirements. This is a major assumption made in this report. Existing boilers produce steam at 450 PSI, 750°F which are also the steam conditions needed for steam going to the extraction and condensing turbines. It is, therefore, assumed that desuperheaters will be installed and will be used when boiler steam is used for process requirements

excluding 40 PSI steam. All new boilers are also designed to produce steam at 450 PSI, 750°F and assumed to be operated as described above.

Economic Factors

Cost of capital (interest rate) is given as 10% per year. Predicting inflation rates is difficult at best. There are some considerations, however, which can make the task somewhat easier and eliminate some uncertainty associated with the forecasts.

Economists generally believe that there is a close relationship between inflation and long term interest rates. Interest rates are believed to consist of a general inflation rate and a real rate; the later component being dependent upon supply and demand conditions. During the post world war period, the real rate (Actual rate less general rate of inflation) on top grade (AAA rated) corporate bonds has been mostly in the 2 to 4 percentage points range. The real rate on federal government commitments has been generally lower (about ½ to 1 percentage points). Based upon above considerations and recognizing that the cost of capital should also include floatation costs, it is clear that a 10% cost of capital to the federal government is consistent with a general inflation rate of about 7 to 8%.

Another consideration in predicting the inflation rates over the operating life of the plant is that the individual cost components, though strongly influenced by general inflation rates, do not necessarily follow the trend exactly. Structural, technological and other factors can also have substantial influences, especially over the long run. Also use of higher inflation rates will inflate operating costs in relation to capital invest-

ment. A prudent analysis should, however, recognize that there is more risk associated with savings which will occur 10, 20 or 30 years from the date of operation. For example, the relationship itself (between inflation and interest rates) might change. Thus, lower than expected inflation rates should be used to reduce the probability of overestimating operating costs in relation to capital costs.

Based upon the above logic, a base case inflation rate of 6% per year over the entire evaluation period (1985 to 2020) is used for all operating cost components, except for the cost of buying electricity from Appalachian Power. It is believed that after attaining a substantially higher base than todays costs, the cost of electricity should go up at a significantly slower rate than the general rate of inflation. Thus, only a 5% inflation rate is used for purchased power costs over the evaluation period (1985-2020).

The inflation rates for various cost components from present to date of operation reflect best possible estimation which can be made. These rates do not have to be based upon the above discussed relationship between inflation and interest rates, especially till the start of construction. The main reason is that the level of interest rates is immaterial until significant cash outlays have been made.

Cost Data

Coal costs for January 1985 are taken as 240 ¢/MBTU (65 $/ton based upon 27 MBTU/ton). These prices, due to spot market buying practices, reflect a 30% premium over those expected under long term contracts. Based upon 130 ¢/MBTU for January, 1976, the January 1985 prices reflect a 7% per year escalation in coal prices. Nuclear fuel costs for January, 1985 are taken as 55¢/MBTU. (See Appendix 3).

The cost of buying electricity from Appalachian Power is taken as 3.5 ¢/Kw-hr for January 1985. This represents an escalation rate of 7% per year. It is believed that because of reasons such as decontrol of domestic oil prices, a trend toward higher rate increases for wholesale customers than that for residential customers, inadequate rate relief granted in the past etc., electricity rates will go up significantly faster than the general rate of inflation for the next few years. After that, the rise in rates should slow down and eventually, on a long term basis, the rates should go up at a significantly lower rate than the general rate of inflation. The later is reflected in the selection of inflation rate for electricity costs over the evaluation period.

The rate schedule to be used is given as "schedule L.C.P." (See Appendix 2) of Appalachian Power Company. This schedule is somewhat regressive, and thus an approach using constant ¢/Kw-hr is subject to some error. It is, however, judged that the effect is not significant as far as the overall conclusions of this study are concerned. (No attempt was made to see if alternate rate schedules might be more economical for one case or the other. It is, however, recommended that a more detailed study should look into this aspect of the problem. Also, an attempt should be made to judge the trends in structure of rate schedules for the particular power company).

Base values selected for capital and operating and maintenance costs for a coal fired boiler plant (with SO_2 removal system) are subject to significant uncertainty. Also, treatment of O&M costs on a $/MBTU basis does not appropriately reflect the distinct characteristics of fixed and variable cost components. A study, presently being done by United Engineers & Constructors Inc., should provide more accurate estimates of these costs.

Load Duration Curves

The load duration curves for steam and electrical requirements of RAAP are shown in figures 4.1 and 4.2 respectively. These curves are formulated as per directions received from DOD personnel. They are based upon an expected average utilization of RAAP at 45% of peak full mobilization requirements. The characteristics of the load duration curve for steam requirements reflects actual usage data for the year 1973. The load duration curve for electrical requirements is assumed to be similar to that for steam requirements. The curves are assumed to be straight lines for simplicity in evaluation. In general higher CNSG steam export capacity is desirable only if it can be utilized. Whether or not this is the case depends on the actual load duration curves for RAAP, which we believe to be adequately represented by the straight line approximation.

The operating characteristics of any particular system are evaluated based upon the single load duration curves for both steam and electricity requirements. In real life, RAAP can be expected to operate, sometimes above and sometimes below its expected average usage. This gives a family of load duration curves. A more accurate method for the economic evaluation will be to estimate operating characteristics and costs for each of these family of curves and compute a weighted average cost based upon the probabilities associated with various outcomes. Thus, the operating characteristics and costs based upon single expected average load duration curves can lead to significant error, especially in extreme situations. One example of such a situation will be when RAAP is expected to operate at 70% of peak full mobilization requirements for half of the time and at 20% for the other half of

the time. The expected average utilization in this case will be 45% of peak full mobilization requirements, the base case for this report. However, it is believed that use of the load duration curves shown in figures 4.1 and 4.2 can lead to significant error in estimating operating characteristics and costs for this case.

<u>Other Data</u>

The availability factor for the PE-CNSG, taken as 85%. The availability factor for steam export from nuclear plant is also taken as 85%, thus neglecting forced outage rates associated with reboiler, etc. The availability factor for electricity export is taken as 83%. This reflects a forced outage of more than 2% for the turbine-generator and associated equipment.

The construction period for the nuclear plant is taken as 36 months. This reflects the period from construction permit to date of operation during which most of the cash outlays are made. The construction period for the steam distribution system is taken as 24 months. This reflects the period before commercial operation in which most of the cash outlays are made for the steam distribution system.

Table 4.1

Base Set of Data For Economic Evaluation

Time References

Date of operation for nuclear plant and other new facilities	January 1985
Operating life of the nuclear plant	35 Years
Evaluation period	1985 to 2020
Reference date for present worth costs	January 1985

RAAP Data (Existing Facilities & Steam Requirements

Full mobilization steam requirements:	
Highest daily average	992,000 #/hr
Peak requirements	1,070,000 #/hr
Peak full mobilization electrical requirements	65.1 MWe
40 PSI steam requirements for building heat (Average 90,000 #/hr for four months during the year)	263×10^6 #/yr
40 PSI steam requirements for process heat	25% of total process steam requirements
Steam conditions required at main plant distribution header for meeting end use requirements (except for 40 PSI steam).	400 PSI, Saturated

Table 4.1 (cont'd)

Expected average utilization (for both steam and electricity) of Radford plant over the evaluation period	45% of peak full mobilization requirements
Load duration curves (steam & electricity)	Figures 4.1 & 4.2
Number of existing boilers (power house in building 400)	5
Steam export capacity of each powerhouse boiler (after rehabilitation)	100,000 #/hr
Boiler design steam conditions	450 PSI, 750°F (294°SH)
Condensate return	None
Average enthalpy of feed water from river	23.1 BTU/#
Number of existing extraction turbines	2
Steam flow capacity per extraction turbine	109,000 #/hr
Rated Gross electrical output per extraction turbine	6 MWe
Number of existing condensing turbines	2
Rated electrical output per condensing turbine	6 MWe
<u>Nuclear Plant Data:</u>	
Availability factor; PE-CNSG	85%
Availability factor for steam export	85%
Availability factor for electricity export	83%
Construction period, nuclear plant	36 months
Construction period, steam distribution system	24 months
Auxiliary power requirements:	
100% process steam case while operating at full capacity	6 MWe
100% electric case while operating at full capacity	7 MWe
Part steam, part electric case when operating at full capacity	7 MWe

Table 4.1 (cont'd)

Recommended design:

Steam export capacity	570,000 #/hr
Steam conditions at reboiler outlet	450 PSI, 26°SH
Gross electrical output	30 MWe
Net electrical output	23 MWe
Data For Boiler Plants	
Boiler efficiency	88%
Construction period	24 months
Boiler design steam conditions	450 PSI, 750°F
Type of coal used	Pulverized
Heating value of coal used	13,600 BTU/#
Steam requirements for feedwater heating	20% of gross steam generated
Boiler steam assumed to be desuperheated to 400 PSI, Saturated, before sent to steam distribution headers	Yes, except when put through extraction turbines while meeting 40 PSI steam requirements
BTU's of coal needed per pound of 40 PSI steam exported and corresponding electricity produced	1,551
BTU's of coal needed per pound of other steam exported	1,342
Auxiliary power requirements (including that for SO_2 removal system) while exporting about 500,000 #/hr of steam	5 MWe
Cost Data	
Fuel costs (coal), January 1985	240 ¢/MBTU
Fuel costs (nuclear), January 1985	55¢/MBTU
Cost of buying electricity from Appalachian Power, January 1985	3.5¢/Kw-hr
Base cost for a boiler plant with one boiler (400,000 #/hr design capacity) and having SO_2 removal system (April 1976)	$20.0 X 10^6
Costing exponent for boiler plants	0.7

Table 4.1 (cont'd)

Increase in cost of boiler plant for each additional boiler	90% of boiler plant with one boiler
Operating & Maintenance costs (January 1985) for boiler plant with SO_2 removal system (Plant size in the range under consideration)	$1,015/$10^9$ BTU of coal used
<u>Economic Factors</u>	
Cost of Capital (Interest rate)	10% per year
Composite escalation rate for plant costs	7% per year
Escalation rate per year over the evaluation period:	
Fuel and O&M Costs	6% per year
Cost of electricity from Appalachian Power	5% per year

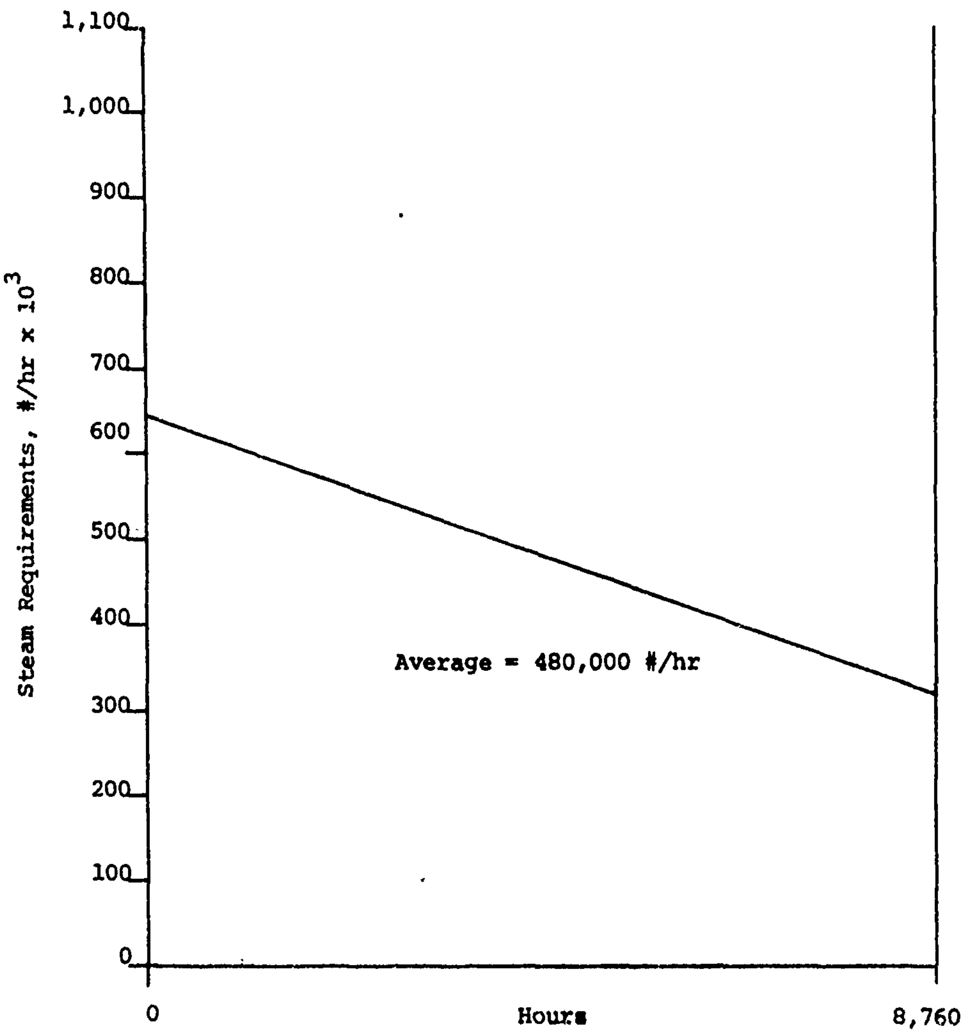


Figure 4.1 Yearly Load Duration Curve for Steam Requirements

Base Case
Expected Average Utilization of RAAP at
45% of Peak Full Mobilization Requirements

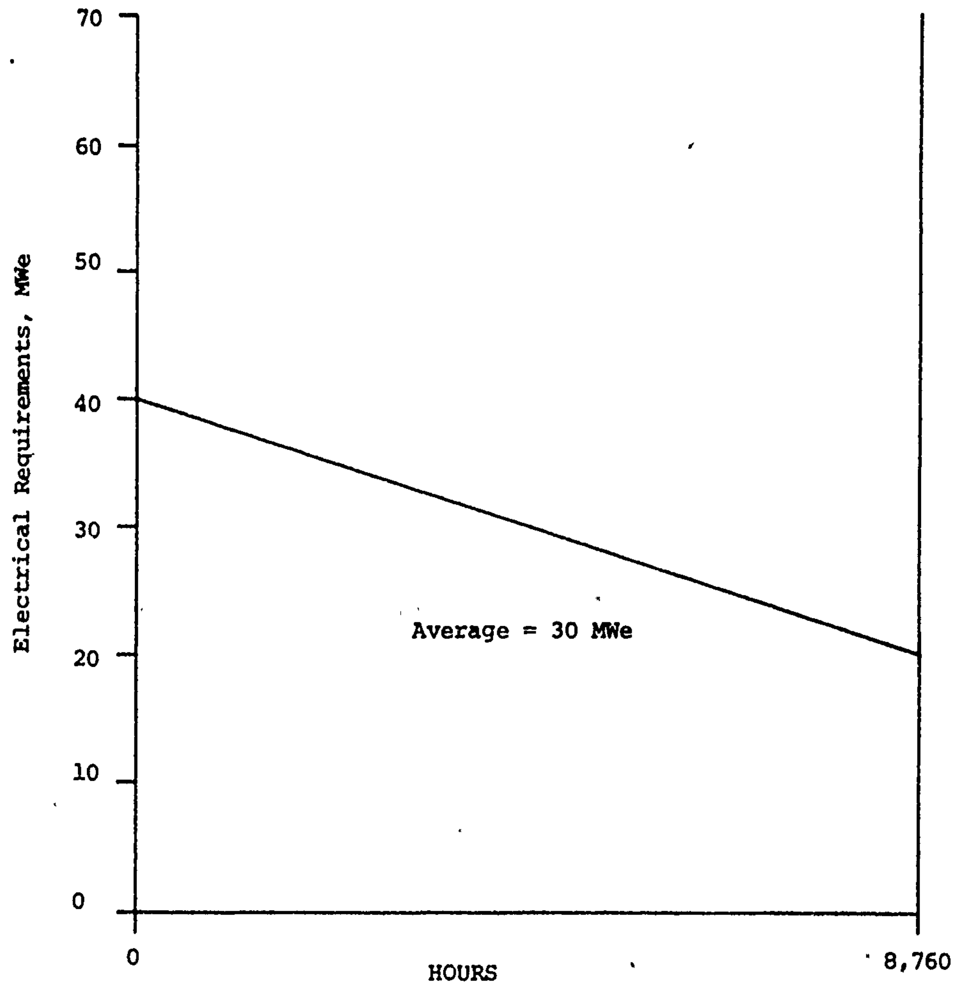


Figure 4.2 Yearly Load Duration Curve For Electrical Requirements

Base Case

Expected Average Utilization of RAAP at

45% of Peak Full Mobilization Requirements

4.5 Optimum Mix Analysis For Nuclear Plant

The PE-CNSG being considered in this report is a fixed capacity machine with a rated thermal output of 313 MW. It can be used to export steam only or electricity only or a combination of both. One of the first tasks was to determine an optimum mix. At the same time, determination of an optimum mix needs information which is dependent upon completion of other tasks which in turn depend on the mix. Thus, basically it is a trial and error approach. In reality, the mix was developed first by making best possible judgements about the outcome of relevant parts of the study. This section, however, shows the analysis for the mix based upon actual data available from other parts of this study. It comes out that the optimum mix remains essentially unchanged from the one initially used.

A combination of steam and electricity from the nuclear plant can be produced in the following ways:

Series Combination

In this case, the steam in the secondary loop first goes through a turbine and then through the reboiler thus producing both steam and electricity. A schematics of this system is shown in Figure 4.3. It is clear that the export steam pressure and temperature conditions will drop, depending upon the amount of electricity produced. The minimum acceptable steam conditions for the Radford plant are, however, unknown. The situation can be best explained by means of an example.

Suppose the steam in the secondary loop is sent through a turbine exhausting at 500 PSI (saturation temperature 467°F). The temperature of export steam from the reboiler will be about 412°F. The pressure should be

about 250 PSI (Saturation temperature 401°F) which allows some superheat to avoid excessive condensation losses in transportation from nuclear plant to the main plant area. After accounting for pressure drop and enthalpy loss during distribution from nuclear plant to the main plant distribution header, the steam might be dry saturated at 200 PSI or a somewhat higher pressure. Based upon the available information, these steam conditions probably would not be acceptable. Also an approximate idea of economics involved can be obtained (assuming the steam conditions are acceptable) as shown below:

Isentropic enthalpy drop in the series turbine

= (1233.5 - 1205) = 28.5 BTU/#

Average expected export steam requirements = 480,000 #/hr.

Assume combined T-G efficiency = 85% steam

Electrical output based upon average expected steam requirements:

$$= \frac{480{,}000}{893{,}000} \times 1.254 \times 10^6 \times \frac{28.5}{3{,}413} \times 0.85$$

= 4,784 KWe

Combined availability factor for PE-CNSG and turbine = 83%

Electricity generated per year = 4,784 x 8,760 x 0.83

= 35 x 10^6 Kw-hr/yr

Savings in electric bill = (35 x 10^6 Kw-hr/yr) x (0.035 $/Kw-hr)
(Jan. 1985 costs)

= 1.22 x 10^6 $/year

Present Worth (January 1985) of savings in electric bill

= 1.22 x 10^6 x (Inflation adjusted PWF)

= 1.22 x 10^6 x 17.7 = $21.6 x 10^6

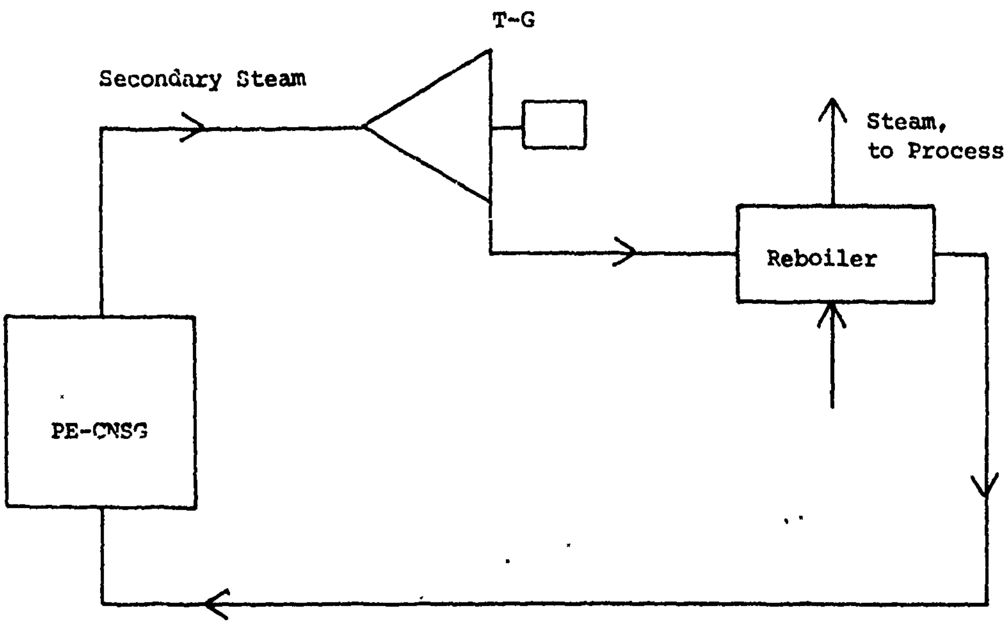


Figure 4.3 Series Combination

Because of extraction type arrangement, the increase in BTU's of nuclear fuel used is only equal to the heat content of the KWe-hrs produced.

Increase in nuclear fuel costs (January 1985 costs)

$$= 35 \times 10^6 \times \frac{3,413}{10^6} \times 0.55 \text{ \$/yr}$$

$$= 66,000 \text{ \$/yr.}$$

Present Worth (January 1985) of increase in nuclear fuel costs

$$= 66,000 \times (\text{Inflation adjusted PWF})$$

$$= 66,000 \times 20 = \$1.3 \times 10^6$$

Present Worth (January 1985) of gross savings less increase in nuclear fuel costs = $\$20.3 \times 10^6$

Besides the additional costs of nuclear fuel already considered, the other cost increases associated with these savings are the equipment, labor and engineering costs associated with turbine generator and associated equipment, building costs for housing the turbine generator and O&M costs for the turbine-generator. Neglecting O&M costs, the increase in base plant cost (April 1976 dollars) which exactly offsets the savings is:

$$= \frac{20.3 \times 10^6}{(1.07)^{7.25} \ (1.1)^{1.5}} = \$10.8 \times 10^6$$

Clearly the increase in direct and indirect plant costs associated with the turbine-generated and associated equipment will wipe out most, if not all the savings which can be realized by going to a series combination. Thus, on balance, the economics of the series combination is marginal, at best. Based upon the above considerations, the series combination is not consid-

ered as a viable alternative. The combined series-parallel combination is also ruled out because of the unacceptability of the series portion.

Thus, the parallel combination is considered as the only viable alternative and is analyzed in detail.

Parallel Combination

In the parallel combination, the secondary steam flow is split into two portions - one going to the reboiler for producing export steam and the other to a turbine in a closed condensing cycle. By varying the design split, the nuclear plant can be used to produce various amounts of export steam and electricity. A schematics of the parallel combination is shown in Figure 4.4.

The economic evaluation for the parallel combination is more complicated than that for a series combination analyzed before. In the parallel combination, the selection of any particular mix has the following effects on the overall system:

(i) The capital cost of the nuclear plant is dependent on the mix selected.

(ii) The amount of export steam capacity available from the nuclear plant is dependent upon the mix selected. Thus, the capacity of supplemental and/or back up facilities needed to provide full mobilization steam requirements with a certain desired reliability is dependent upon the mix selected.

(iii) The size and the capital costs of the steam distribution system from the nuclear plant to the main plant distribution headers

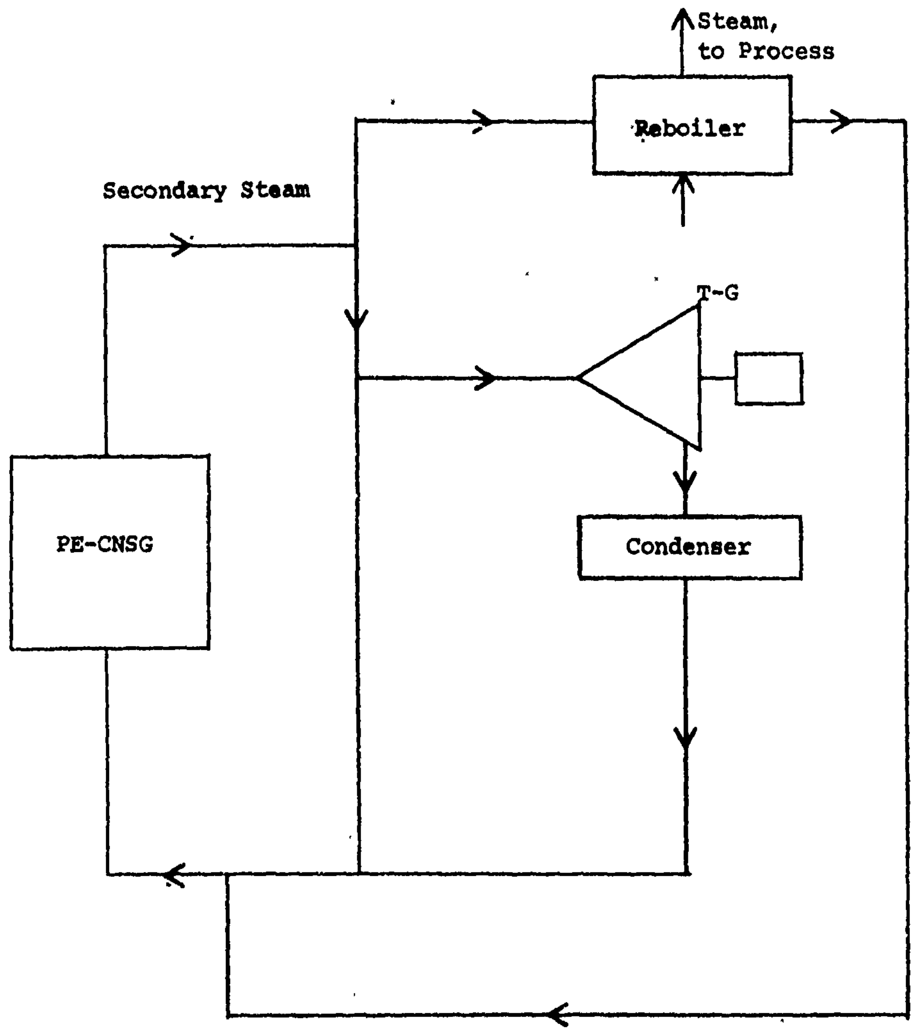


Figure 4.4 Parallel Combination

is dependent upon the steam export capacity and thus the mix selected for the nuclear plant. The electrical transmission lines are also similarly affected by the mix selected.

(iv) The amount of steam which will have to be exported by boiler facilities to meet total requirements of the Radford plant is dependent upon the steam export capability of the nuclear plant. Thus boiler fuel and O&M costs are also dependent upon the mix selected.

(v) The overall capacity factor attained for the PE-CNSG and thus the associated nuclear fuel and also O&M costs are dependent upon the mix selected.

(vi) The amount of electricity purchased from Appalachian Power is dependent upon the electrical generating capacity of the nuclear plant and thus the mix selected.

Clearly, the mix selected for the nuclear plant affects the design, operation and economics of the whole system. Thus, a total systems approach is taken for finding an optimum mix. Alternative mixes are selected for the nuclear plant and for each mix, the capital costs of the nuclear plant, the steam distribution steam and supplemental and/or backup boiler capacities needed, is evaluated. Also, based upon the load duration curves, etc., the amount of steam and electricity exported by the nuclear plant, the amount of steam and electricity (if any) exported by the boiler plants and the amount of electricity purchased from Appalachian Power is estimated for each particular mix so as to provide total steam and electrical requirements of RAAP in an optimum manner. From these data, total annual operating costs are found for each

particular mix. Finally, capital and operating costs are appropriately combined to arrive at total present worth comparative owning and operating costs for each particular mix thus leading to the selection of an optimum mix.

System Design For Alternate Mixes

Table 4.2 shows alternate mix designs considered for the nuclear plant. The gross electrical output in each case is based upon assuming no extraction points in the turbine and no feed water heaters. A part of secondary steam going for electricity generation is directly mixed with the condensate from turbine exhaust to maintain necessary conditions of feed water going into the reactor.

Table 4.3 gives system designs for alternate mixes selected for the nuclear plant. All the cases represent equivalent reliability based upon an effective load carrying capacity of 800,000 #/hr which is equivalent to that for the total coal fired system planned for the Radford plant. Four out of five existing powerhouse boilers (each with an export capacity of 100,000 #/hr) are assumed to be available almost all of the time and thus represent an effective export capacity of 400,000 #/hr. The capacity of new boiler facilities needed (assumed coal fired plants) is on the basis that if the largest unit in the system is not available, the system should still have a steam export capacity of 800,000 #/hr. For cases I through IV, the nuclear plant is the largest steam exporting unit in the system. Thus, for each of these cases, the recommended 400,000 #/hr of new boiler export capacity in conjunction with an existing effective capacity of 400,000 #/hr will provide a total export capacity of 800,000 #/hr when the nuclear plant is not

available. For Case V, the new boiler with an export capacity of 400,000 #/hr becomes the largest unit in the system and, thus, an additional boiler with an export capacity of 46,000 #/hr is needed. This looks like an odd combination of boilers; however, its main purpose is to illustrate that at this point, the cost of new boiler facilities needed will start going up. (Two boilers each with an export capacity of 200,000 #/hr are also adequate for Case V. The cost of these two boiler facilities will be still higher than that of a single 400,000 #/hr export capacity boiler plant).

It should be noted that the cost of the new boiler facilities will remain constant from Cases I through IV, even though the steam export capacity of the nuclear plant is progressively reduced. This is significant because it shows that up to a certain point, the generation of electricity does not carry with it a capital cost charge for steam generating equipment. It also shows that proper cost allocation is important and reflects the characteristics of RAAP and how the nuclear plant fits in it.

It was mentioned before that the various cases shown in Table 4-3 have equal reliability. Strictly speaking, the reliability is slightly higher for cases with a higher steam export capacity of the nuclear plant. This corresponds to the situation when all or most of the existing and new boiler facilities are not available. The probability of this happening is indeed very small; however, should it occur, the system with nuclear plant having a higher steam export capacity will be more fully able to meet the steam requirements of the Radford plant.

System Operation For Alternative Mixes

Table 4.4 gives average yearly operating data for system with nuclear plant having alternate mixes. These data are developed so as to meet the expected steam and electrical loads (as given by load duration curves) in an optimum way. Thus, the nuclear plant, which has the lowest operating costs, is used to the maximum possible extent to meet energy requirements. In case of steam, the rest of the requirements are met with fossil boilers. No distinction is made between steam produced by existing or new boilers, thus, implicitly assuming an equal efficiency for both.

In case of electricity, the remainder of the requirements are met by buying electricity from Appalachian Power. The net electricity available (gross less auxiliary power & SO_2 removal system requirements) corresponding to the operation of extraction turbines is small and is neglected. The economics of condensing turbines over purchased power is doubtful and it is assumed that no electricity is produced by the operation of condensing turbines. For a more complete discussion of the best way to meet Radford energy requirements, please refer to Section 4.7 titled "Strategy For System Operation". Also Appendix 3 shows supporting calculation for operating data corresponding to Case III in Table 4.4.

It should be noted that Case I (100% steam case) in Table 4.4 shows a negative number for electricity exported by nuclear plant. This is because of the auxiliary power requirements of the plant.

Total Comparative Owning & Operating Costs

Table 4.5 gives total comparative capital investment costs for system with nuclear plant having alternate mixes.

The capital cost of the nuclear plant consists of a component such as the PE-CNSG and the reactor plant equipment which is independent of the mix, a component which is a function of steam export capability and another component which is a function of electric export capability. Based upon this logic, the cost estimates for 100% steam and 100% electric cases and the estimate for the mix recommended, the following cost model is developed for the nuclear plant as a function of mix. The costs are only base costs and do not include contingency, escalation and interest during construction.

Base cost (4/1976) for the nuclear plant is:

$$= \$1{,}000 \left[71{,}900 + 28{,}600\ (X)^{0.605} + 51{,}500\ (1-X)^{0.605} \right]$$

Where X = Actual steam export capability as a fraction of 100% steam export capability which is 893,000 #/hr

The steam distribution system includes the distribution system from nuclear plant to main plant header and the distribution system from main plant to steam header in the horse shoe area. The cost of the first part is a function of mix where as the cost of the second part is independent of the mix. Based upon this logic, the base cost (4/1976) of the steam distribution system as a function of mix is:

$$= \$1{,}000 \left[1{,}200 + 2{,}200\ \left(\frac{Y}{570{,}000}\right)^{0.7} \right]$$

Where Y = design steam export capacity of the nuclear plant, #/hr.

The final capital costs for the date of operation (1/1985) are developed in accordance with the method of economic evaluation described in section 4.3 .

Table 4.5 shows a plot of total comparative present worth owning and operating costs and also the capacity factor for the PE-CNSG as a function of mix. It can be seen that the capacity factor keeps going up as the gross electrical output is increased till it peaks at about 35 MWe. The total present worth owning and operating costs are lowest when the nuclear plant has a gross electrical output of 30 MWe and a net steam export capacity of 570,000 #/hr. This is the optimum mix selected for the nuclear plant.

Alternate Mix Designs Considered For The Nuclear Plant

Table 4.2

Mix No.	Secondary Steam Flow (#/hr x 10^3) For		Gross Electrical Output, MWe	Nuclear Plant Auxiliary Power Requirements when Operating at Full Capacity, MWe	Net Plant Electrical Output, MWe	Net steam export capacity, #/hr x 10^3
	Electricity Generation	Steam Production				
I	--	1,254	--	6	(6)	893
II	303	951	20	7	13	677
III	454	800	30	7	23	570
IV	605	649	40	7	33	462
V	757	497	50	7	43	354

System Design For Alternate Mixes

Selected For The Nuclear Plant

Table 4.3

			Nuclear Plant Mix				
Mix No.			I	II	III	IV	V
Nuclear Plant Design Capacity	Electrical, MWe	Gross	-	20	30	40	50
		Net	(6)	13	23	33	43
	Steam Export, #/hr x 10^3		893	677	570	462	354
Existing effective boiler steam export capacity, #/hr x 10^3			400	400	400	400	400
New boiler facilities needed, steam export capacity, #/hr x 10^3			1 @ 400	1 @ 400	1 @ 400	1 @ 400	1 @ 400 1 @ 46
New boiler facilities needed, Boiler design capacity = 1.25 x export capacity, #/hr x 10^3			1 @ 500	1 @ 500	1 @ 500	1 @ 500	1 @ 500 1 @ 60
Total installed new steam export capability, #/hr x 10^3			1,293	1,077	970	862	800
Existing total steam export capability, #/hr x 10^3			500	500	500	500	500
Total installed steam export capability, #/hr x 10^3			1,793	1,577	1,470	1,362	1,300

Table 4.4

Average Yearly Operating Data for System with Nuclear Plant Having Alternate Mixes

			Nuclear Plant Mix				
	Mix No.		I	II	III	IV	V
Nuclear Plant Design Capacity	Electrical, MWe	Gross	-	20	30	40	50
		Net	(6)	13	23	33	43
	Steam Export, #/hrx10^3		893	677	570	462	354
Nuclear Plant							
Steam exported (#/yr x 10^6)			3,574	3,574	3,518	3,205	2,622
Electricity exported (kW-hr/yr x 10^6)			(37)	95	166	209	218
Total Nuclear fuel used (Btu/hr x 10^9)			4,273	6,168	7,017	7,197	6,616
Capacity Factor for PE-CNSG (%)			46.0	65.0	75.0	76.9	70.7
Boiler Plants							
40 PSI steam exported (#/yr x 10^6)			158	158	172	250	396
Other steam exported (#/yr x 10^6)			473	473	515	750	1,187
Total steam exported (#/yr x 10^6)			631	631	687	1,000	1,583
Electricity produced (Net of auxiliary power and SO_2 removal system requirements) while exporting 40 PSI steam (kW-hr/yr x 10^6)			Small	Small	Small	Small	Significant Neglected
Total Coal Used (Btu/yr x 10^9)			880	880	957	1,394	2,207
Appalachian Power							
Total electricity bought (kWhr/yr x 10^6)			300	168	97	54	45

Table 4.5

Total Comparative Capital Investment Costs ($\$ \times 10^3$)
System with Nuclear Plant Having Alternate Mixes

			Nuclear Plant Mix				
		Mix No.	I	II	III	IV	V
Nuclear Plant Design Capacity	Electrical, MWe	Gross	-	20	30	40	50
		Net	(6)	13	23	33	43
	Steam Export, #/hrx10^3		893	677	570	462	354
Base Costs							
Nuclear Plant			100,500	117,900	121,600	124,300	126,200
New Boiler facilities			23,400	23,400	23,400	23,400	28,700
Steam distribution system			4,200	3,700	3,400	3,100	2,800
Total Base Cost (4/1976)			128,100	145,000	148,400	150,800	157,700
Escalation To Start of Construction and during Construction (7% per year)			82,600	93,300	95,500	97,000	101,700
Interest During Construction			29,900	34,100	35,000	35,600	37,000
Total Cost (1/1985)			240,600	272,400	278,900	283,400	296,400
Contingency (10%)			24,100	27,200	27,900	28,300	29,600
Total Comparative Capital Investment (1/1985)			264,700	299,600	306,800	311,700	326,000

Table 4.6

Total Comparative Owning & Operating Costs ($ x 10^3)
System with Nuclear Plant Having Alternate Mixes

			Nuclear Plant Mix				
		Mix No.	I	II	III	IV	V
Nuclear Plant Design Capacity	Electrical, MWe	Gross	–	20	30	40	50
		Net	(6)	13	23	33	43
	Steam export, #/hrx10^3		893	677	570	462	354
Capital Investment							
Total Comparative Capital (1/1985)			264,700	299,600	306,800	311,700	326,000
Annual Operating Costs							
Nuclear Fuel Costs			2,350	3,392	3,859	3,958	3,639
Boiler Fuel (Coal) Costs			Base	--	185	1,234	3.185
Nuclear Plant O&M Costs			Base	236	308	344	338
Boiler Plant O&M Costs			Base	--	78	522	1,347
Electricity From Appalachian Power			10,500	5,880	3,395	1,890	1,575
Total Annual Operating Costs			12,850	9,508	7,825	7,948	10,084
Present Worth (1/1985) of Annual Operating Costs			232,900	176,600	148,700	154,600	198,000
Total Comparative Present Worth Owning & Operating Costs (1/1985)			497,600	476,200	455,500	466,300	524,000

4.6 Recommendation For Back Up Energy Source

The recommended optimum mix design for the nuclear plant provides a steam export capacity of 570,000 #/hr and a net electrical capability of 23 MWe. The existing power house has five boilers each with a net steam export capability of 100,000 #/hr after rehabilitation. The usual practice is to operate only four of these boilers at a time with the fifth as a standby. The power house also has four turbines with a gross generating capacity of 24.0 MWe. Peak full mobilization requirements are 1,070,000 #/hr of steam and 65.1 MWe of electricity. Thus, supplemental and/or back up sources of supply are needed for both steam and electrical requirements.

(1) Back Up For Steam Requirements

(a) Available Alternatives

Basically there are three kinds of plants namely coal, oil and nuclear which can be used as a backup source of steam. The nuclear plant is a highly capital intensive machine with low fuel costs. Since the back up is expected to be operated for only a fraction of the time during the year (except during years of high levels of mobilization), the nuclear plant is obviously not a logical choice.

An oil fired plant has lower capital costs but higher fuel costs as compared to a coal fired plant with SO_2 removal system. Once again since the back up is expected to be operated for only a fraction of the time during the year (except during years of high levels of mobilization), an oil fired plant can be competitive and possibly more economical as compared to a

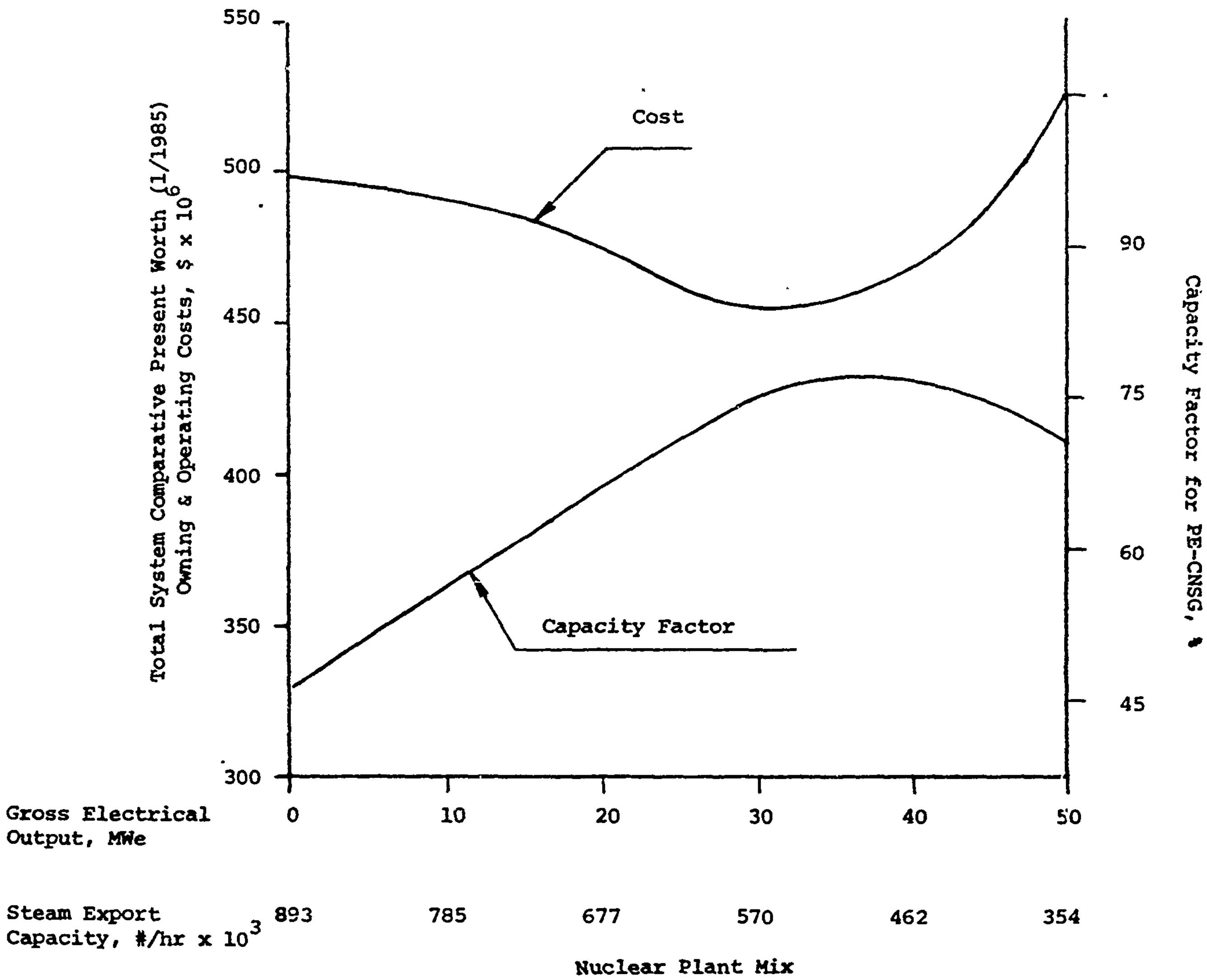


Figure 4.5 Effect of Nuclear Plant Mix on Capacity Factor for PE-CNSG and Total System Present Worth Owning & Operating Costs

coal fired plant. However, besides economics, there are other considerations which must be taken into account before a selection is made between the two alternatives.

Just prior to the oil embargo, the United States was importing approximately 30% of its oil requirements. This dependency on foreign sources has now grown to about 40% of requirements. Though steps are being taken to reduce this dependency, it is believed that the country will keep importing a substantial portion of its oil requirements for a long period of time. Thus, an oil fired plant, which will tend to increase our reliance on foreign sources, is most likely detrimental to national interests.

Furthermore, the back up energy source is expected to have its maximum usage at times of high mobilization. This is also the time when there is a higher probability of foreign countries trying to use oil as a political and/or military weapon. Thus, an oil fired plant might not be usable just when it is most needed.

Based upon the above considerations, a coal fired plant is selected for use as a back up source of steam.

(b) Back Up Capacity Requirements

The size and number of back up boilers is dependent upon the desired level of reliability for meeting steam requirements. A very high level of desired reliability will mean a large back up capacity and possibly more than one back up boiler resulting in a high additional capital investment. On the other hand, a low level of desired reliability will mean a

small back up capacity and possibly no back up at all. Thus, there are trade offs between additional reliability achieved and additional capital investment required. Before going further into the question of back up capacity requirements, it is worthwhile to see what reliability really means for a defense installation like RAAP.

Reliability considerations for the Radford plant differ in significant ways from classical reliability considerations for an electric utility system. In the later situation, there is a large number of users and it is almost impossible to communicate with all of them in a short period of time. Thus, the occurrence of a black out etc. has tremendous economic as well as social costs (robbery, etc.). This helps explain the very high reliability target sought by electric utilities.

For the case of RAAP, the plant itself and associated buildings etc. are the only users of steam. Also production is on site and thus a much better integration is possible between source and user facilities. Thus, scheduled outages will not disrupt production of explosives etc. but can only effect the level of production. Forced outages in which some warning time is available will have similar effects except that some of the work force also might not be utilized for some time.

Also, in times of high levels of mobilization, the Radford plant should be able to produce the desired amount of ammunition over a certain period of time. Production does not have to match consumption over short periods of time. This is because of the fact that there is always an inventory of vital ammunition and that transportation of the ammunition from RAAP to the final users point should take place only at finite time intervals.

The above considerations point toward the possibility that reliability considerations need not be based upon full mobilization requirements. In fact, the total coal fired system planned for the Radford plant provides for only three additional coal fired boilers each with a steam export capacity of 200,000 #/hr. These new boilers, combined with five existing power house boilers each with an export capacity of 100,000 #/hr, represent an effective load carrying capacity* of about (2 x 200,000 + 4 x 100,000) or 800,000 #/hr as compared to peak full mobilization requirements of 1,070,000 #/hr.

For a nuclear plant system to provide equivalent reliability, the back up boiler should have an export capacity of 400,000 #/hr. Thus, when the nuclear plant is not available, the system will have an export capacity of 400,000 #/hr effective from existing power house boilers and 400,000 #/hr from the back up boiler for a total of 800,000 #/hr. The total coal fired system as perceived by Radford and the

*Effective capacity represents capacity available almost all of the time.

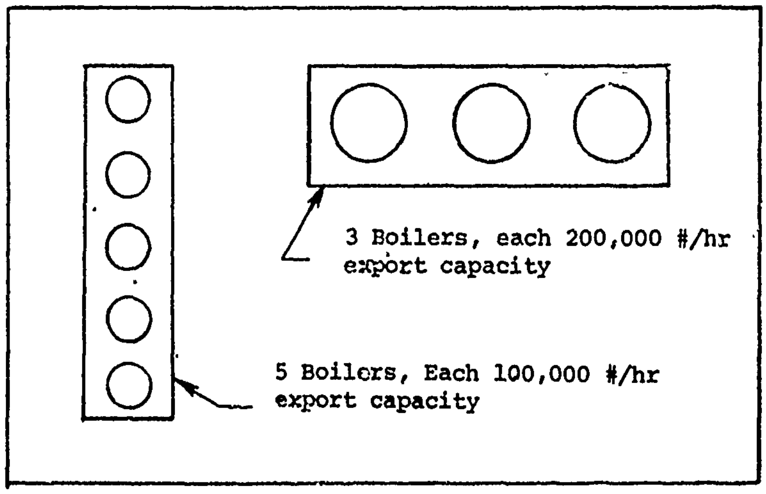
system with nuclear plant having equivalent reliability are shown in Figure 4.6.

It should be pointed out that the availability factor for the nuclear plant is only 85% as compared more than 90% for a boiler plant for steam export. Also, the system with nuclear plant has larger units as compared to those in the total coal fired system. It is believed, however, that these adverse factors are off-set by a higher total installed steam export capacity (1,470,000 #/hr for the system with nuclear plant as compared to only 1,100,000 #/hr for the total coal fired system).

System reliability consists of various available capacities and the probabilities associated with them. Since the nuclear plant capacity and availability factor is different than those for every unit in the total coal fired system, it is impossible to design a system with nuclear plant to have exactly the same reliability as that for the total coal fired system. Thus, the two systems shown in figure 4.6 have equivalent reliabilities in the sense that they are roughly comparable.

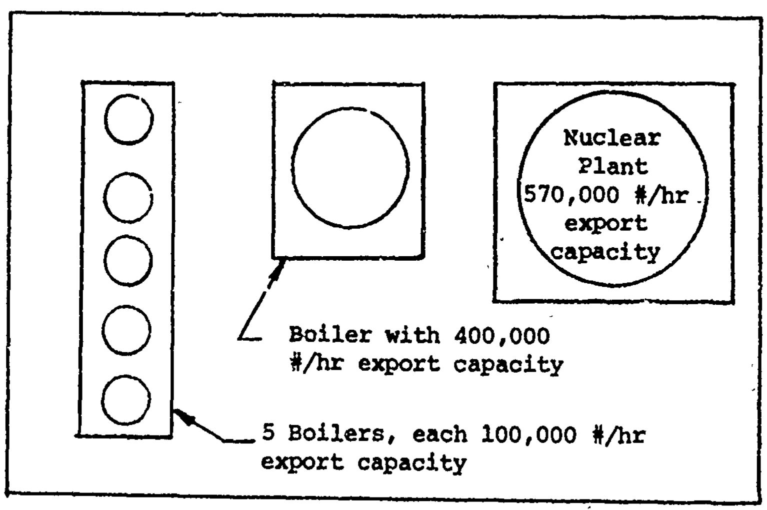
The case shown in figure 4.6 is taken as the base case for this report. As mentioned before, reliability considerations reflect trade-off between incremental reliability and corresponding incremental capital investment. Table below shows size of back up for various reliability considerations.

Total Coal Fired System



Total Installed Steam Export
Capacity = 1,100,000 #/hr

System with Nuclear Plant for Reliability
Equivalent to the Total Coal Fired System



Total Installed Steam Export
Capacity = 1,470,000 #/hr

Figure 4.6

Reliability Considerations Based Upon	Back Up Boiler Net export Capacity
1,000,000 #/hr	600,000 #/hr
900,000	500,000
800,000 (Base Case)	400,000
700,000	300,000
600,000	200,000
400,000	--

For selecting between alternative steam flows upon which reliability considerations should be based, an evaluation should be made as to the value of incremental reliability. This should be compared with incremental capital investment and incremental fixed maintenance costs associated with respective back ups. (Usually a higher capacity machine will have larger fixed maintenance costs).

Another cost consideration in selecting a back up boiler capacity is the efficiency and variable maintenance costs associated with existing powerhouse boilers (after rehabilitation) as compared to new boilers. The reason for this is that different back up capacities will mean different extents of steam production from new back up boiler and existing power house boilers. This is especially true when only small back up capacity is considered. For example, when reliability considerations are based upon 400,000 #/hr of steam, no back up capacity is needed. In this case, power house boilers

will have to meet all steam requirements whenever the nuclear plant is not available (15% of the time) and whenever steam requirements exceed 570,000 #/hr (nuclear plant capacity). However, if a back up boiler of say 200,000 #/hr export capacity was installed, it will be given priority over existing powerhouse boilers in meeting steam requirements (assuming it is more efficient than existing powerhouse boilers after rehabilitation, which will probably be the case). This will substantially reduce the use of existing power house boilers resulting in operating savings as well as increase in life of these boilers.

So far in this section, no consideration was given to the question of reactor scram. This is the situation in which the reactor has to be shut down with a little or no warning time at all. This can result in a sudden loss of steam supply resulting in product damages etc. One way to alleviate this problem is to have the back up boiler in hot shutdown and manned all the time. This, however, can be expensive and should be compared with the costs associated with reactor scram and the probability associated with such an occurrence.

It should also be noted that at times of high levels of mobilization, some of the boiler facilities will also be active in meeting steam requirements. At such times, boiler output can be increased if a reactor scram occurs. This will tend to reduce the costs associated with a reactor scram.

In times of low levels of mobilization, the nuclear plant will be the only machine providing steam requirements. A reactor scram in such times might mean a complete loss of steam supply. However, the fact that the RAAP is operating at low level of mobilization might mean that the cost associated with reactor scram will not substantial.

(2) Back-Up For Electricity Requirements

The available electrical capability in a system with nuclear plant will be 24 MWe gross from four existing turbines in the power house and 23 MWe net from the nuclear plant. Peak full mobilization requirements are 65.1 MWe. Thus supplemental and backup sources are needed to provide electricity requirements at high levels of mobilization.

The additional required capacity can be provided either by additional on-site generating facilities or by connecting to Appalachian Power company system. On-site generating facilities will require substantial capital investment even though most of their usage will only be at times of high levels of mobilization. Furthermore, the reliability of a total on-site electrical generation system will be substantially less than that of the Appalachian Power System except with huge capital investments. Clearly, the Appalachian Power system should be used as a supplemental and backup source of electrical energy to provide total system requirements.

The existing tie line with Appalachian Power provides for a minimum electrical capacity of 30 MWe. It is understood that this tie line capacity can be increased to 50 MWe by changing instrument

transformers at both ends and increasing the capacity of Morgan's transformer. This 50 MWe of capacity from Appalachian Power combined with projected on-site capacity should be more than adequate for meeting projected electrical requirements with acceptable reliability. The exact amount of capacity to be contracted should be based upon reliability standards which are consistent with those for steam requirements. This is because electrical and steam requirements are closely interrelated. Also due consideration should be given to minimum charges associated with contract capacity as shown in "Schedule L.C.P." (See Appendix 4.)

4.7 Strategy For System Operation

Once the nuclear plant and the recommended back up are installed, the optimum way of meeting any given load is determined only by various fuel and O&M (mainly variable) costs. Capital costs become "sunk costs" and are thus irrelevant for the analysis.

Nuclear plant has the lowest fuel and variable O&M costs and should be used to the maximum extent to meet both steam and electricity requirements. However, as far as 40 PSI steam requirements are concerned, the extraction turbines offer the dual advantage of providing both 40 PSI steam and electricity. The economics are therefore not obvious and the following evaluation is made.

The extraction turbines have a capacity of approximately 218,000 #/hr of 40 PSI steam and 12,000 MWe gross electrical output. Thus in one hour, 218,000 # of 40 PSI steam and 12,000 kW-hr of electricity can be provided. Various alternatives to provide these steam and electrical outputs are

considered and the associated costs evaluated for January 1985.

Alternative 1 Extraction Turbines Used

The associated fuel costs are those associated with exporting 218,000 # of steam at 450 PSI, 750°F from the boilers.

BTU's of coal used = 218,000 x 1,551 = 338 x 10^6 BTU

Fuel cost at $2.40/MBTU

= 338 x 2.4 = $811

Alternative 2 Nuclear Plant Used

In this case, the nuclear plant is assumed to have enough unused steam and electrical capacity to provide the before mentioned amounts. This situation is likely when the Radford plant is operating at very low levels of mobilization. The associated fuel costs are the sum of those associated with exporting 218,000 # of steam and those associated with producing 12,000 kWe-hr of electricity.

BTU's of nuclear fuel

= BTU's for steam + BTU's for electricity

$$= \left(\frac{218,000}{893,000} + \frac{454,000}{1,254,000} \times \frac{12.0}{30.0}\right) \times 313,000 \times 3,413$$

= 416 x 10^6 BTU

Fuel Cost at $0.55/MBTU

= 415 x 0.55 = $228

Alternative 3 Nuclear Plant for Steam and Appalachian Power for Electricity

In this case, the nuclear plant is assumed to have enough unused steam capacity but no unused electrical capacity. This situation is possible in

times of high electricity demand and when the Radford plant is operating at intermediate levels of mobilization. Thus, 40 PSI steam requirements can be proved by the nuclear plant but the 12,000 kWe-hr of electricity will have to be bought from Appalachian Power.

Cost of nuclear fuel for exporting 218,000 # of steam

$$= \frac{218,000}{893,000} \times 313,000 \times \frac{0.55}{106} = \$143$$

Cost of buying 12,000 kW-hrs (at 3.5 ¢/kW-hr)

$$= 12,000 \times \frac{3.5}{100} = \$420$$

Total Cost = 143 + 420 = $563

The table below summarizes the total costs associated with various alternatives considered above.

Alternate No.	Method of providing 218,000 # of 40 PSI steam and 12,000 kW-hr of electricity	Total Costs (January, 1985)
1.	Extraction turbines used in conjunction with boilers	$811
2.	Nuclear plant used for both 40 PSI steam and electricity production	$228
3.	Nuclear plant used for 40 PSI steam, electricity purchased from Appalachian Power Company	$563

The list above is not exhaustive but only represents most likely alternatives available under normal operating conditions. It can be seen that both alternatives 2 and 3 are substantially more economical than alternative 1. The

above analysis, however, does not consider variable O&M costs associated with various alternatives. These costs are minimal in case of alternatives 2 and 3; but can be significant for alternative 1. This makes alternatives 2 and 3 even more economical as compared to alternative 1.

Clearly, the nuclear plant should be given the priority over existing extraction turbines for meeting 40 PSI steam requirements. As already mentioned before, the nuclear plant should also be given highest priority for meeting all electrical and other steam requirements.

In cases when the nuclear plant cannot provide total steam requirements, the next priority should be given to extraction turbines operated with the back-up boiler. Of course, the extraction turbines can be used only to the extent of 40 PSI steam requirements and the amount of electricity produced is automatically determined by such requirements.

The next priority for meeting steam requirements should go to the new back up boiler and then to existing power house boilers. This is based upon the assumption that the new back up boiler will have high r efficiency and lower maintenance costs as compared to existing power house boilers (after rehabilitation). Also, this will prolong the life of existing power house boilers thus delaying the installation of replacement facilities.

In case of meeting electrical requirements also, the nuclear plant carries the top priority. The next order of priority should go to electricity available from the operation of extraction turbines. In reality, when the extraction turbines are being operated so as to meet steam require-

ments in an optimum fashion (as outlined earlier in this section), the electrical requirements will be high enough so as to be able to utilize all the electricity available from the nuclear plant as well as the extraction turbines.

The other available sources of electricity are Appalachian Power and existing condensing turbines. The comparative economics, however, are not obvious. Assuming a net heat rate of 12,000 BTU/kWe-hr for electricity generation from existing condensing turbines and based upon $2.40/MBTU for coal, the fuel costs for electricity generated from condensing turbines come out to 2.9¢/kW-hr. This alone compares favorably with 3.5¢ kW-hr for purchased electricity; however, the associated O&M costs can be substantial. This is especially true because the condensing turbines are old. Also a significant crew force might have to be brought in just for operation of condensing turbines. It is, therefore, believed that Appalachian Power should be given priority over condensing turbines. The exact economics, however, should be carefully evaluated for the particular situation. For example, when RAAP is operating at high levels of mobilization, the back-up boilers will also be operating and thus the incremental number of people associated with operation of condensing turbines should be small. Also, at such times, these turbines can be operated at almost full capacity. This can give them a significant economic advantage over purchased power.

The overall strategy for system operation is summarized below:

<u>Steam Requirements (including 40 PSI steam)</u>

<u>Order of Priority</u>:

Nuclear Plant

Back-up boiler with extraction turbines

Back-up boiler

Existing power house boilers

<u>Electricity Requirements</u>

<u>Order of Priority</u>:

Nuclear Plant

Electricity available from operation of extraction turbines

Appalachian Power Company	Priority depends upon particular situation
Condensing turbines	

4.8 Cost Analysis (Nuclear vs. Fossil)

This section deals with economic evaluation of a system with nuclear plant vs. an all coal fired system for meeting total steam and electricity requirements of RAAP. Comparative economics is shown for base case when expected average utilization of RAAP is equal to 45% of peak full mobilization requirements and also for cases when expected average utilization is at 35% and 55% of peak full mobilization requirements. In all cases, the nuclear plant is

assumed to have a steam export capacity of 570,000 #/hr and a net electrical capability of 23 MWe which is the optimum mix based upon expected average utilization at 45% of peak full mobilization requirements.

Table 4.7 gives average yearly operating data for the base case for a system with nuclear plant and an all-coal fired system. The steam exported by boiler plants is divided into two categories; namely, 40 PSI steam and other steam. The reason is that the amount of electricity produced by the operation of extraction turbines is dependent upon the amount of 40 PSI steam exported. This is significant for an all-coal fired system. Also, it is assumed that the superheated steam (450 PSI, 750^{o}F) from the boilers will be desuperheated in case of "other steam exported". This is done to keep the operating costs for an all coal fired system on the same basis as that for a system with nuclear plant. (For the latter system, it is assumed that the distribution system in the main plant area can be revamped so that 400 PSI, saturated steam at the distribution header is acceptable for meeting end use requirements.) It also becomes clear that the Btu's of coal required per pound of "other steam exported is less than that for 40 PSI steam exported. (In the later case, desuperheating is accomplished by the use of extraction turbines, thus producing electricity also.) A more complete discussion of these aspects and the supporting calculations for Table 4.7 are given in Appendix 1.

Table 4.8 gives comparative capital investment costs for both nuclear and fossil systems. Base costs for the nuclear plant and the steam distribution system are taken from Section 3.9. Table 4.10 gives total owning and operating costs for the two systems. The annual operating costs (before present worthing) are based upon January 1985 prices and are computed by using unit prices in

conjunction with Table 4.7 which gives average yearly operating data for each system.

Operating and maintenance costs for the nuclear plant were developed based on industry data and are shown in Table 4.9 for the base case. For all other cases where the capital cost and capacity factor for the nuclear plant are different from those for the base case, the following equation is used.

Yearly O&M (January 1985) for the nuclear plant is:

= \$ 4,099,000 + 1,581.25(cc)(3.0 + 1.25 cf)

Where cc = capital cost (in millions of dollars) for the nuclear plant (excluding interest during construction but including contingency)

and cf = overall capacity factor for the CNSG

The present worth (1/1985) of annual operating costs is found by applying appropriate inflation adjusted present worth factors to component annual operating costs.

Table 4.10 shows that for the base case, the system with nuclear plant has a slight economic advantage over an all coal fired system. Table 4.12 gives total system comparative owning and operating costs when the expected average usage of Radford plant is 35% and 55% of peak full mobilization requirements. It can be seen that for the lower level of expected utilization, the all coal fired system has a significant economic advantage over the system with nuclear plant. For higher level of expected utilization, the system with nuclear plant has a significant economic advantage over the all coal fired system. On balance, the data so far shows that the two systems

are competetive. It should be pointed out that Table 4.12 is based upon the nuclear plant having the same mix as that for the base case. Thus, this table reflects effects of uncertainty in predicting the expected utilization of RAAP. However, it does not accurately reflect comparative economics if the expected utilization itself was changed to 35% or 55% in which case, the optimum mix will probably change to the advantage of the nuclear plant. This aspect is further discussed in Section 4.10.

Table 4.7

Average Yearly Operating Data (Nuclear vs Fossil)
Base Case

	System With Nuclear Plant	All Coal Fired System
Nuclear Plant		
Steam exported (#/yr x 10^6)	3,518	
Electricity exported (Kw-hr/yr x 10^6)	166	
Total Nuclear Fuel Used (BTU/yr x 10^9)	7,017	
Capacity factor for PE-CNSG (%)	75.0	
Boiler Plants		
40 PSI steam exported (#/yr x 10^6)	172	1,248
Other steam exported (#/yr x 10^6)	515	2,957
Total steam exported (#/yr x 10^6)	687	4,205
Electricity produced (Net of auxiliary power and SO_2 removal system requirements) while exporting 40 PSI steam (Kw-hr/yr x 10^6)	--	25
Total Coal Used (BTU/yr x 10^9)	957	5,904
Appalachian Power		
Total electricity bought (Kw-hr/yr x 10^6)	97	238

Table 4.8

Total System Comparative Capital Investment Costs ($\$ \times 10^3$)
Nuclear Vs Fossil
Base Case

	System With Nuclear Plant	All Coal Fired System
Base Costs (4/1976)		
Nuclear Plant	121,600	-
New Boiler Plant	23,400	40,300
Steam Distribution System	3,400	1,200
Total Base Cost (4/1976)	148,400	41,500
Escalation to start of construction and during construction (7% per year)	95,500	28,600
Interest during construction	35,000	7,000
Total Cost (1/1985)	278,900	77,100
Contingency (10%)	27,900	7,700
Total Capital Investment (1/1985)	306,800	84,800

Table 4.9

Yearly Operating & Maintenance Costs For The Nuclear Plant

Base Case

Staff	$3,000,000
Fixed Maintenance	819,000
Variable Maintenance	256,000
Supplies	611,000
Administrative & General*	469,000*
Nuclear Insurance:**	
Commercial	275,000
Government	9,000
Operating Fees	20,000
Total Yearly Operating & Maintenance Costs (1/1985)	$5,459,000

*Includes such items as headquarters staff, office supplies, and other similar off-site general overhead expenses. Estimates are conservative.

**Insurance costs are estimated in accordance with those for commercial installations. Government owned facilities have been self insured and the actual costs are probably much less then those shown above.

Table 4.10

Total System Comparative Owning & Operating Costs ($ x 10^3)

Nuclear Vs Fossil

Base Case

	System With Nuclear Plant	All Coal Fired System
Capital Costs		
Total Capital Investment (1/1985)	306,800	84,800
Annual Operating Costs		
Nuclear Fuel Costs	3,859	-
Boiler Fuel (Coal) Costs	2,299	14,170
Nuclear Plant O&M Costs	5,459	-
Boiler Plant O&M Costs	972	5,993
Cost of buying electricity from Appalachian Power	3,395	8,330
Total Annual Operating Costs	15,984	28,493
Present Worth (1/1985) of annual operating costs*	311,900	550,700
Total Present Worth Comparative Owning & Operating Costs (1/1985)	618,700	635,500

*Present Worth Costs are found with the use of Inflation Adjusted Present Worth Factors. A sample case, giving year by year operating costs, is presented in Appendix 8.

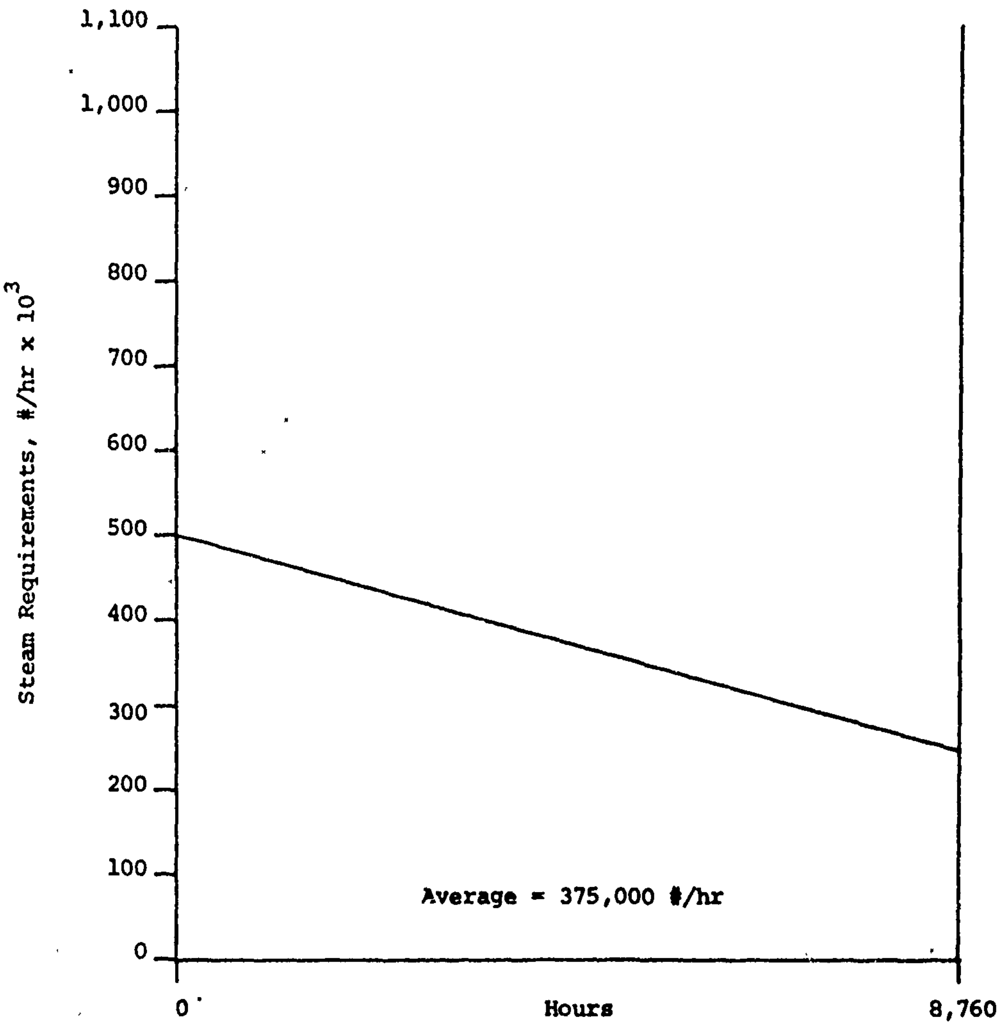


Figure 4.7 Yearly Load Duration Curve for Steam Requirements

Expected Average Utilization of RAAP at

35% of Peak Full Mobilization Requirements

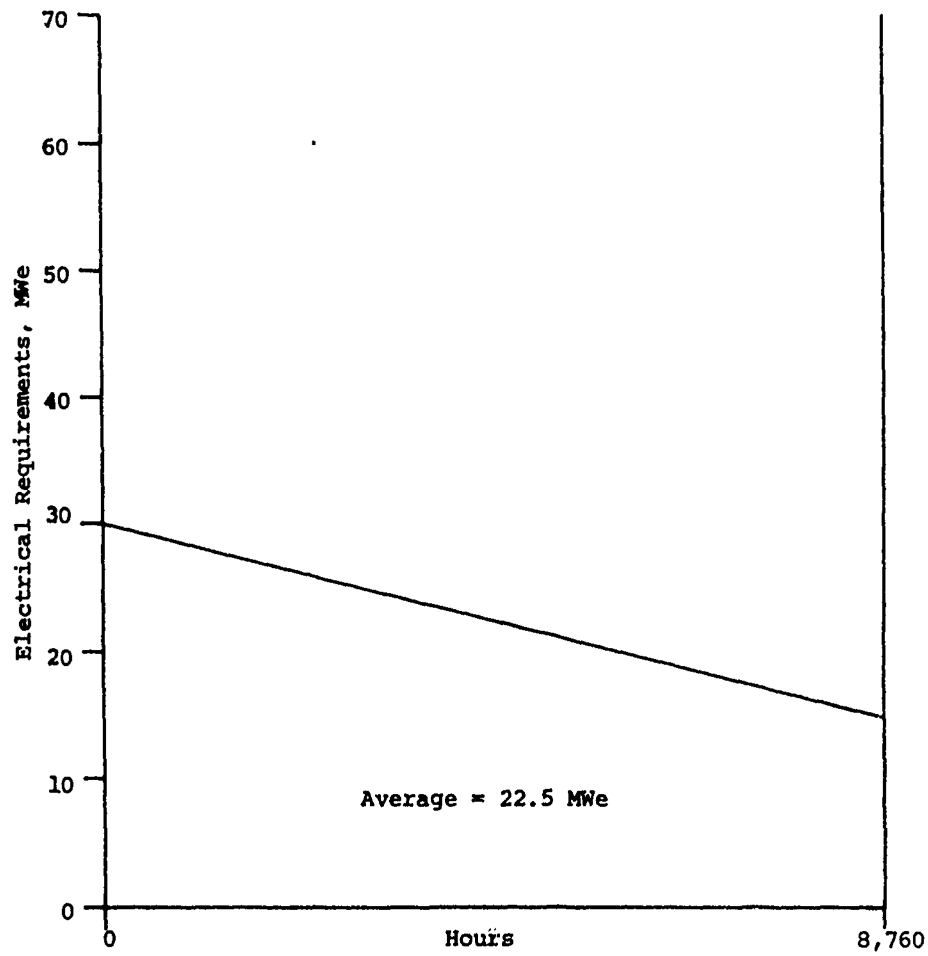


Figure 4.8 Yearly Load Duration Curve for Electrical Requirements

Expected Average Utilization of RAAP at

35% of Peak Full Mobilization Requirements

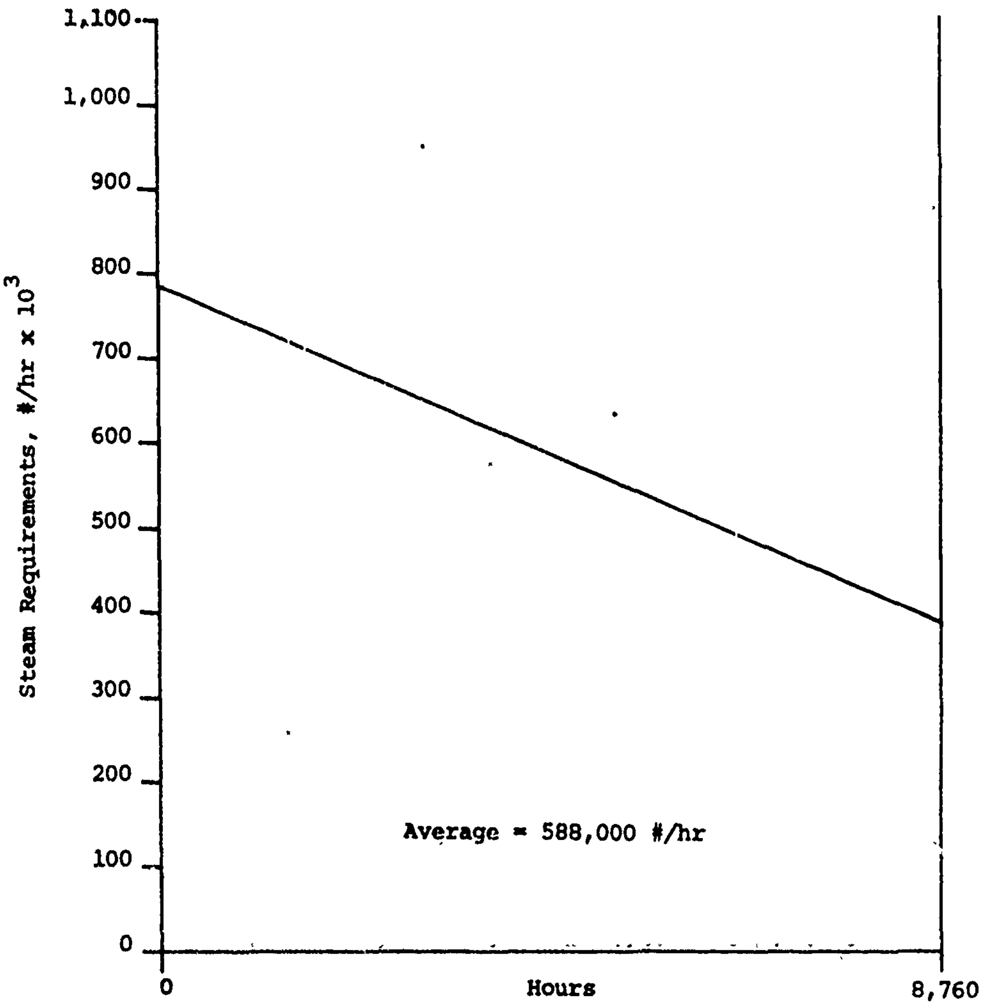


Figure 4.9 Yearly Load Duration Curve for Steam Requirements

Expected Average Utilization of RAAP at

55% of Peak Full Mobilization Requirements

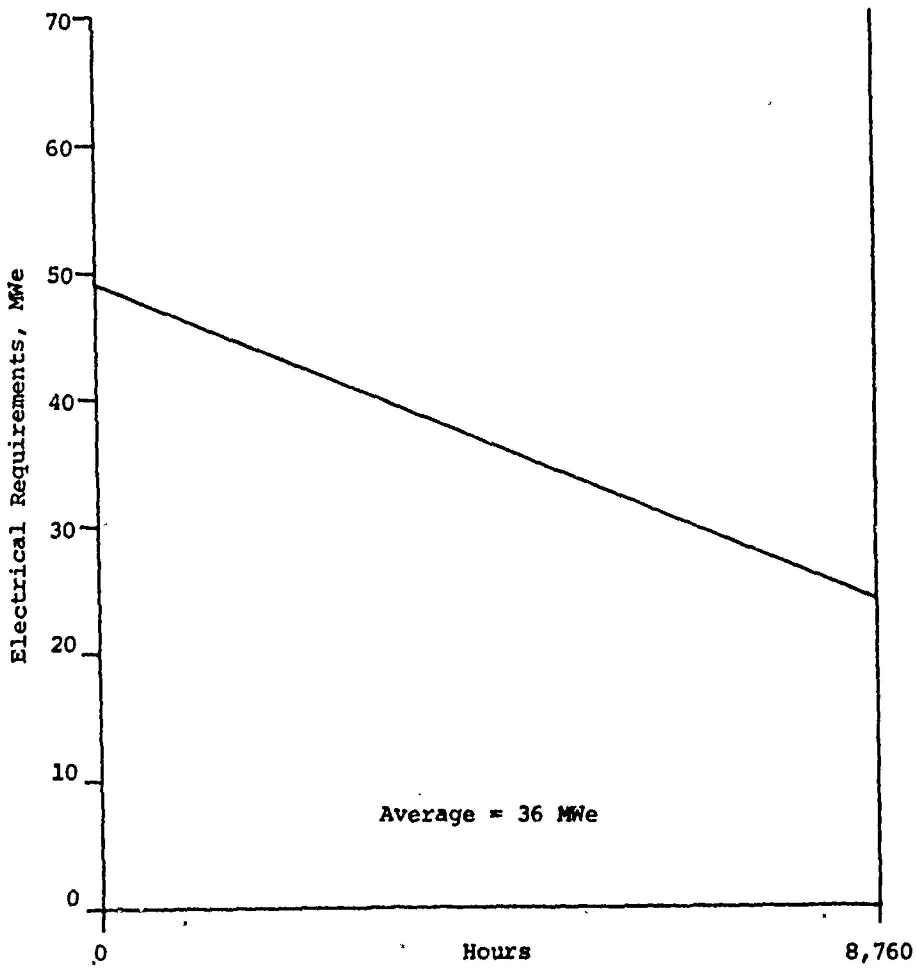


Figure 4.10 Yearly Load Duration Curve for Electrical Requirements

Expected Average Utilization of RAAP at

55% of Peak Full Mobilization Requirements

Table 4.11

Average Yearly Operating Data (Nuclear vs. Fossil)

Alternate Levels of Mobilization

	Expected Average Utilization of Radford Plant as % of Peak Full Mobilization Requirements			
	35%		55%	
	System with Nuclear Plant	All Coal Fired Sys	Sys with Nuc Plant	All Coal Fired Sys
Nuclear Plant				
Steam exported (#/hr x 10^6)	2,792		3,943	
Electricity exported (Kw-hr/yr)	152		168	
Total Nuclear Fuel Used (Btu/yr x 10^9)	5,968		7,550	
Capacity Factor for PE-CNSG (%)	63.8		80.7	
Boiler Plants				
40 PSI steam exported (#/yr x 10^6)	123	1,018	[illegible]02	1,485
Other Steam exported (#/yr x 10^6)	370	2,267	906	3,666
Total steam exported (#/yr x 10^6)	493	3,285	1,208	5,151
Electricity produced (net of auxiliary power and SO_2 removal system requirements) while exporting 40 PSI steam (kW-hr/yr x 10^6)	-	12	-	38
Total Coal Used (Btu/yr x 10^3)	687	4,621	1,684	7,223
Appalachian Power				
Total electricity bought (kW-hr/yr x 10^6)	45	185	147	277

Table 4.12

Total System Comparative Owning & Operating Costs ($ x 10^3)

Nuclear Vs Fossil

Alternate Levels of Mobilization

	Expected Average Utilization of RAAP As % of Peak Full Mobilization Requirements			
	35%		55%	
	System With Nuclear Plant	All Coal Fired System	System With Nuclear Plant	All Coal Fired System
Capital Costs				
Total Capital Investment (1/1985)	306,800	84,800	306,800	84,800
Annual Operating Costs				
Nuclear Fuel Costs	3,282	--	4,152	--
Boiler Fuel (Coal) Costs	1,649	11,090	4,042	17,335
Nuclear Plant O&M Costs	5,410	--	5,483	--
Boiler Plant O&M Costs	697	4,690	1,709	7,331
Cost of Buying Electricity from Appalachian Power	1,575	6,475	5,145	9,695
Total Annual Operating Costs	12,613	22,255	20,531	34,361
Present Worth (1/1985) of annual Operating Costs	248,600	430,200	398,800	664,900
Total Present Worth Comparative Owning & Operating Costs (1/1985)	555,400	515,000	705,600	749,700

4.9 Significant Parameter Identification

The economic evaluation presented so far was based upon a base set of data. Some of this data such as 1985 fuel costs etc. needs assumption about the future and is clearly subject to significant uncertainty. Other data such as base cost estimates for the nuclear plant are subject to change due to such factors as changes in environmental and/or safety standards, estimating errors etc. This section deals with the effect on comparative economics of changes in individual parameters and identifying those parameters which can have a significant effect on the evaluation.

The parameters selected for sensitivity analysis are availability factor for the PE-CNSG; coal, nuclear fuel and purchased electricity costs; Base capital cost estimates, construction period, operating life and O&M costs for the nuclear plant; O&M costs for the boiler plants; escalation rate for base capital costs and escalation rate for the evaluation period. Their effect on comparative economics is shown in figures 4.11 through 4.21.

The range selected for various parameters is based upon the degree of uncertainty believed to be associated with those parameters and represents values which have a reasonable chance of occurrence. It does not include extreme possibilities with a very small chance of occurrence. Also, when various parameters are, in part, affected by a single common factor, the range selected for individual parameters is one which has reasonable possibility of occurrence without significantly affecting the values of other parameters. For example, coal, nuclear fuel and plant capital costs are all affected (to one extent or another) by the general rate of inflation in the economy. A very substantial change in assumption about coal prices would

probably also mean that nuclear fuel and plant capital costs are going to be significantly different from their base case values. The range selected for coal prices should, therefore, be such that the values therein have a reasonable possibility of occurrence without significantly affecting the base values for nuclear fuel and plant capital costs.

The cost of capital (interest rate) affects the capital costs for the facilities and the present worth of annual operating costs (by affecting the inflation adjusted present worth factor). The construction period for the nuclear plant is only three years and the effect of cost of capital on capital costs is not expected to have a significant effect on the overall evaluation.

Inflation adjusted present worth factor is affected by cost of capital (i), escalation rate (e) per year over the evaluation period and the number of years (n) in the evaluation period. This can be seen from the following equation:

Inflation Adjusted PWF (For $i \neq e$)

$$= \frac{1 + i}{i - e} \left[1 - \left(\frac{1 + e}{1 + i} \right)^n \right]$$

For $n = 35$ years, the values of inflation adjusted PWF are shown below for various values of i and e.

i (%)	e (%)	(i - e) %	Inflation Adjusted PWF
6	3	3	22.4
10	7	3	22.7
14	11	3	23.0
6	2	4	19.6
10	6	4	20.0
14	10	4	20.3
6	1	5	17.3
10	5	5	17.7
14	9	5	18.0

It can be seen that even a substantial change in the cost of capital produces only a small change in the value of inflation adjusted PWF, as long as the differential between i and e is kept constant. The reason is that the inflation adjusted PWF almost boils down to a simple PWF for an interest rate equal to the real interest rate (i - e).

Section 4.4 of this report pointed out that historically, the differential between interest rate and general rate of inflation has varied only in a narrow range. Thus, the effect of interest and escalation rates (over evaluation period) on comparative economics can be effectively demonstrated by varying (i - e) in a reasonable range. Figure 4.21 accomplishes this by varying escalation rate only and keeping the interest rate constant at 10%.

It is now possible to see the value of coordinating interest and escalation rate variations. Sensitivity analysis based upon independent changes in one or the other would have shown such wide fluctuations in comparative economics as to make it almost useless to the decision maker. Figure 4.21 still shows that escalation rate can have a substantial effect on comparative economics but the range of possible outcomes has been narrowed down considerably and should prove more meaningful for decision making purposes.

Based upon figures 4.11 through 4.21, the parameters which can have a substantial/significant effect on comparative economics are identified. The parameters which can have a substantial effect on comparative economics are:

1. Coal prices
2. Base cost estimates for the nuclear plant
3. O&M costs for boiler plants
4. Availability factor for the PE-CNSG
5. Escalation rate for various operating costs over the evaluation period.

Parameters which can have a significant effect on comparative economics are:

1. Nuclear Fuel Costs
2. Purchased electricity costs
3. Plant life (Evaluation period)
4. Nuclear plant O&M costs
5. Escalation rate per year for base capital costs

It should be pointed out that effect of changes in expected utilization of RAAP is considered in the following section (Section 4.10) and is found to have a very substantial impact on comparative economics.

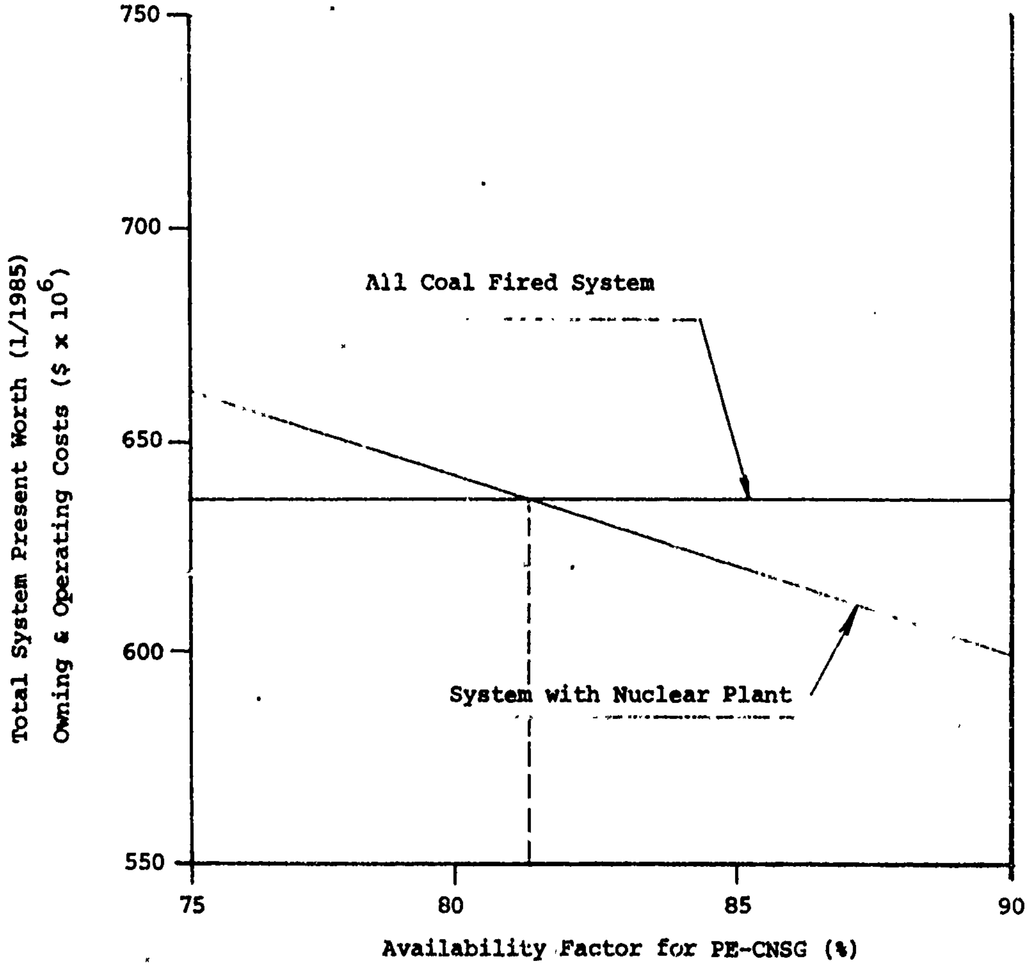


Figure 4.11 Effect of Availability Factor for CNSG on Comparative Economics

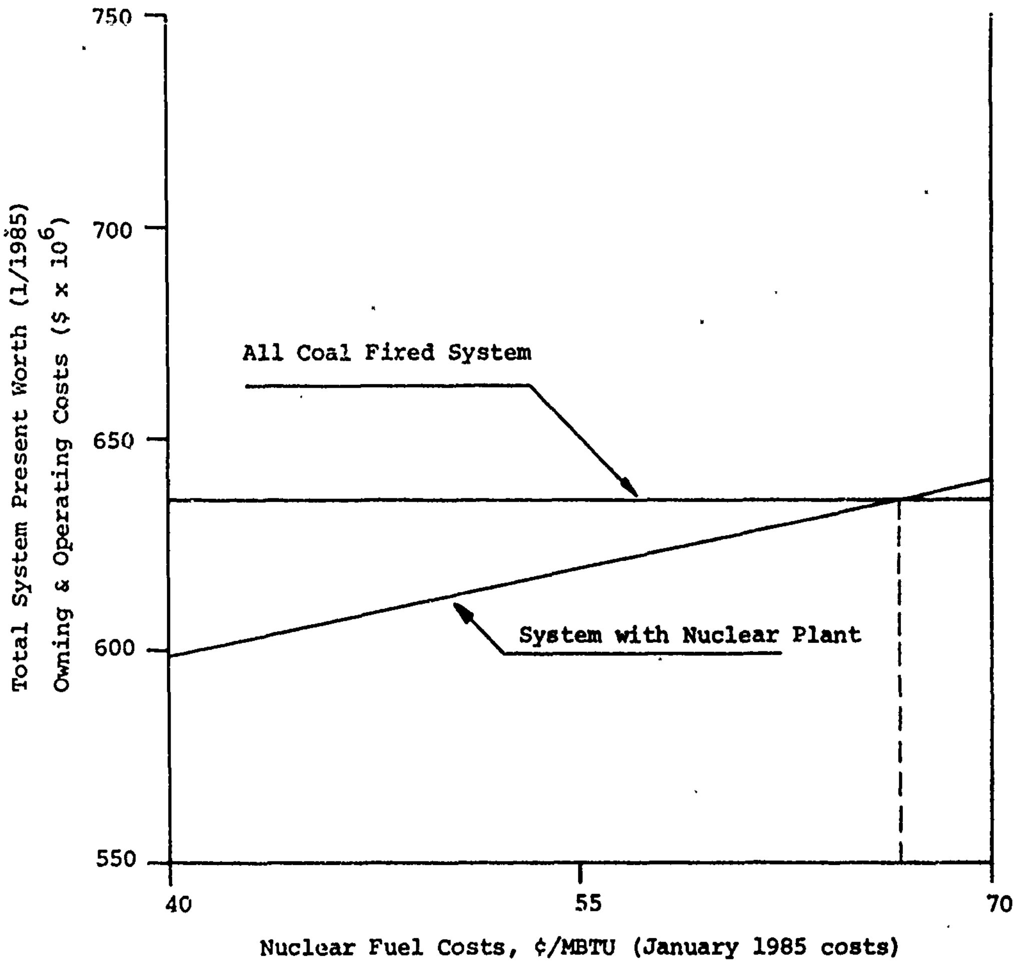


Figure 4.12 Effect of Nuclear Fuel Costs on Comparative Economics

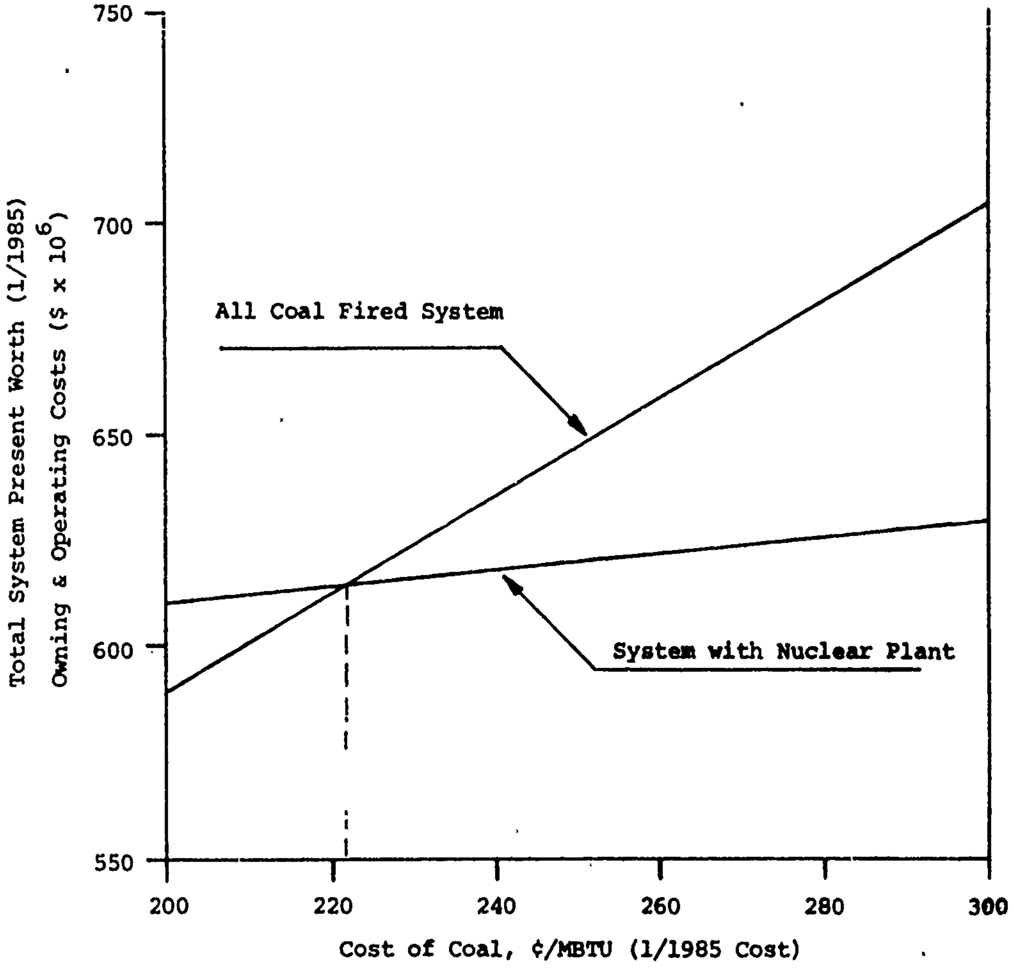


Figure 4.13 Effect of Coal Prices on Comparative Economics

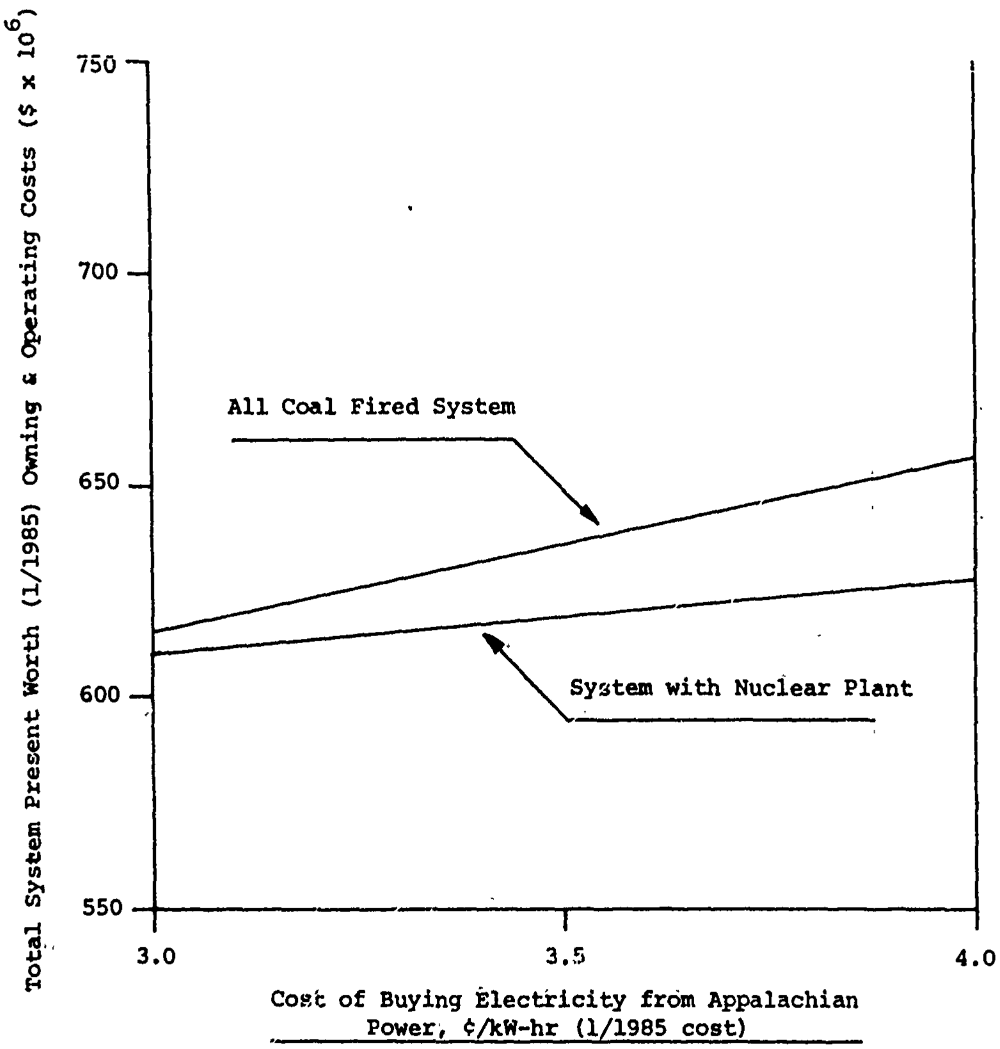


Figure 4.14 Effect of Cost of Buying Electricity on Comparative Economics

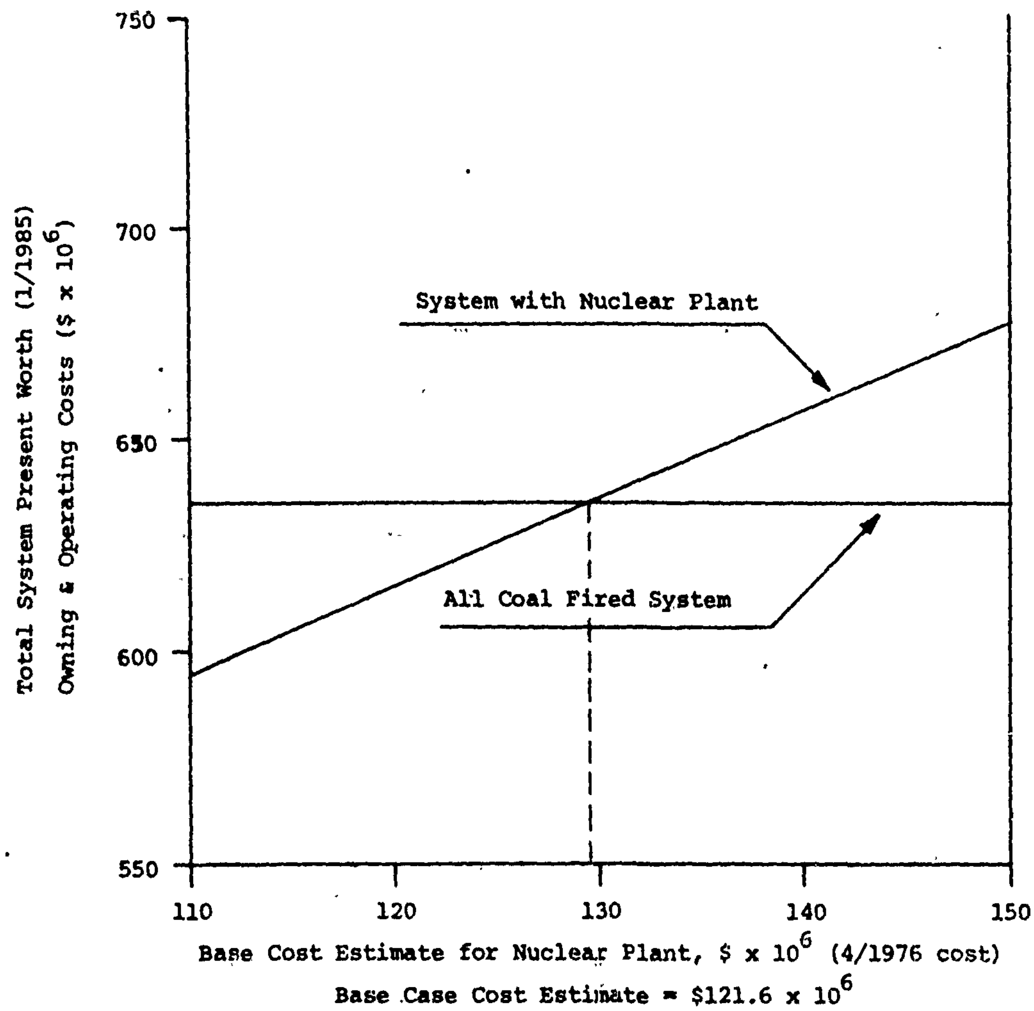


Figure 4.15 Effect of Base Cost Estimate for Nuclear Plant on Comparative Economics

Note: For each case, a 10% contingency is added when finding capital costs for 1/1985

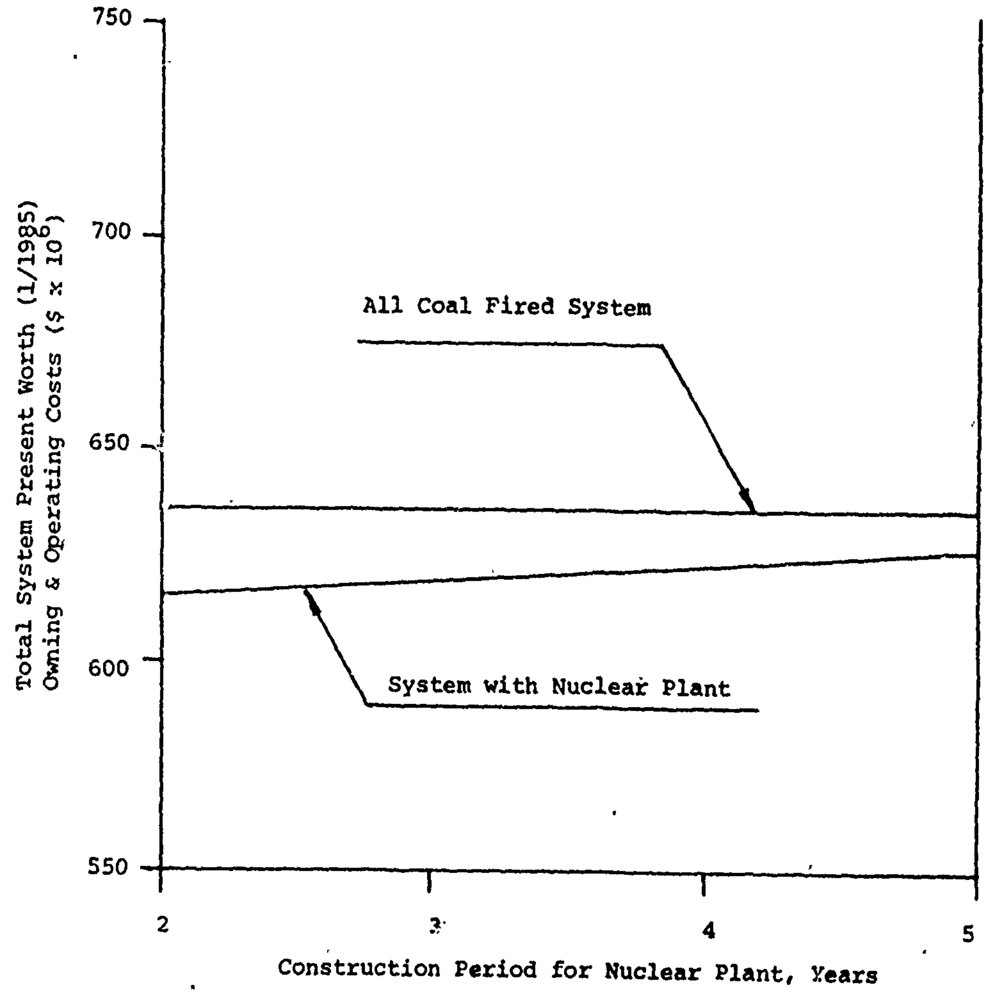


Figure 4.16 Effect of Construction Period for Nuclear Plant on Comparative Economics

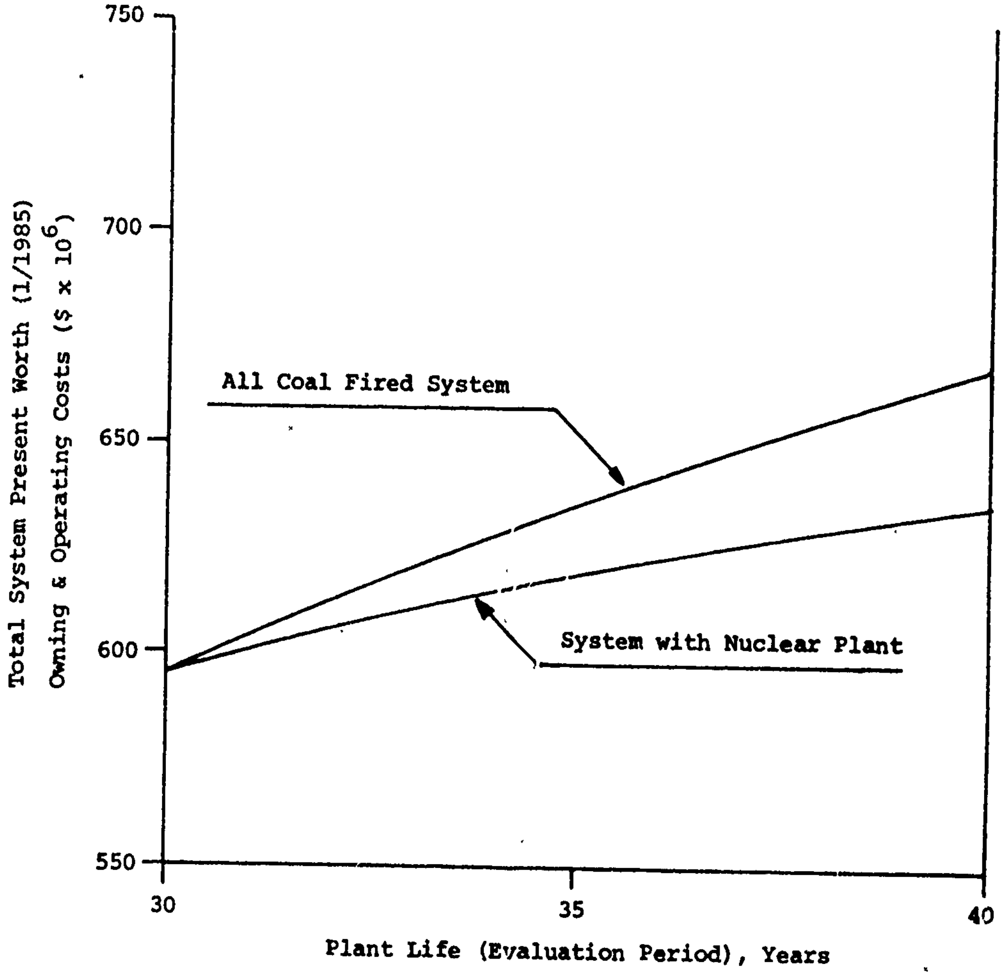


Figure 4.17 Effect of Plant Life on Comparative Economics

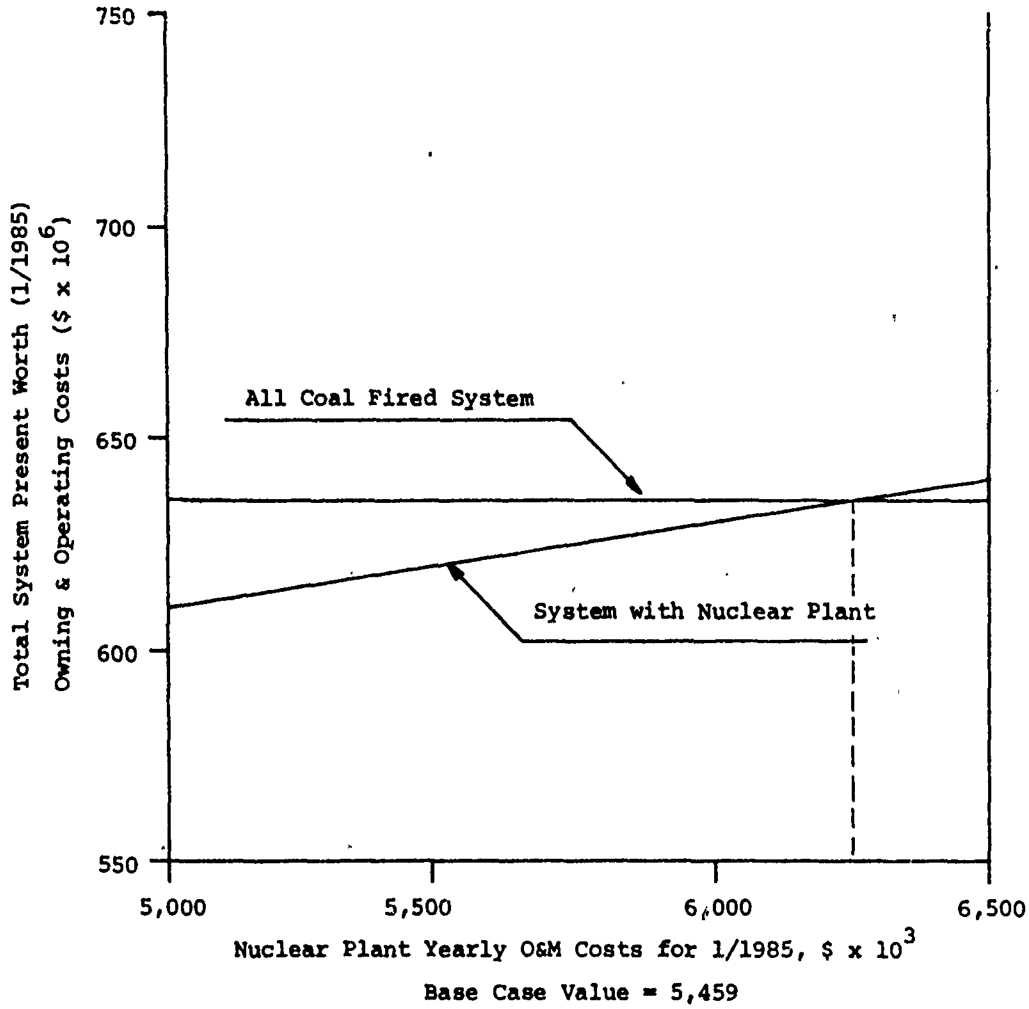
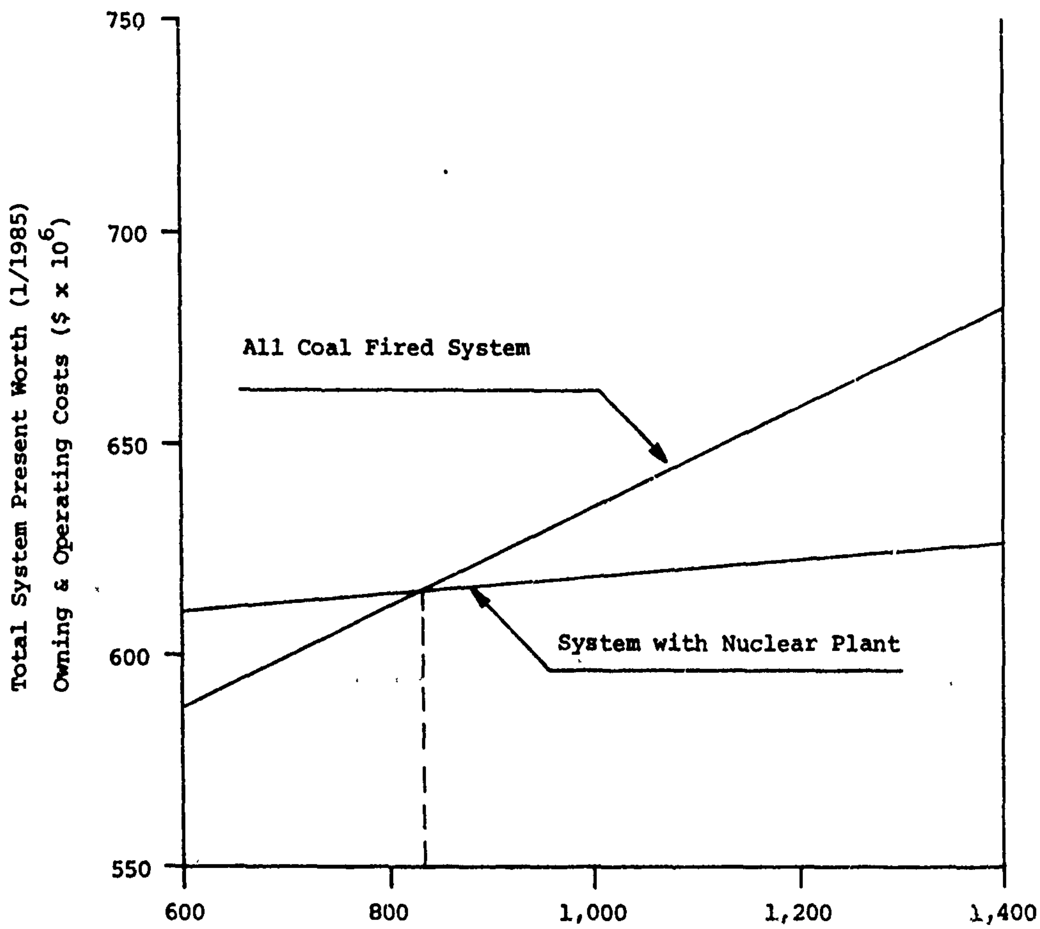


Figure 4.18 Effect of Nuclear Plant O&M Costs on Comparative Economics



O&M Costs (1/1985) For Boiler Plant, $\$/10^9$ Btu's of Coal Used

Base Case Value = 1,015

Note: For a coal fired electric plant, 1,000 $\$/10^9$ Btu's of coal used converts to about 10 mills/kWhr (1/1985)

Figure 4.19 Effect of O&M Costs for Boiler Plant on Comparative Economics

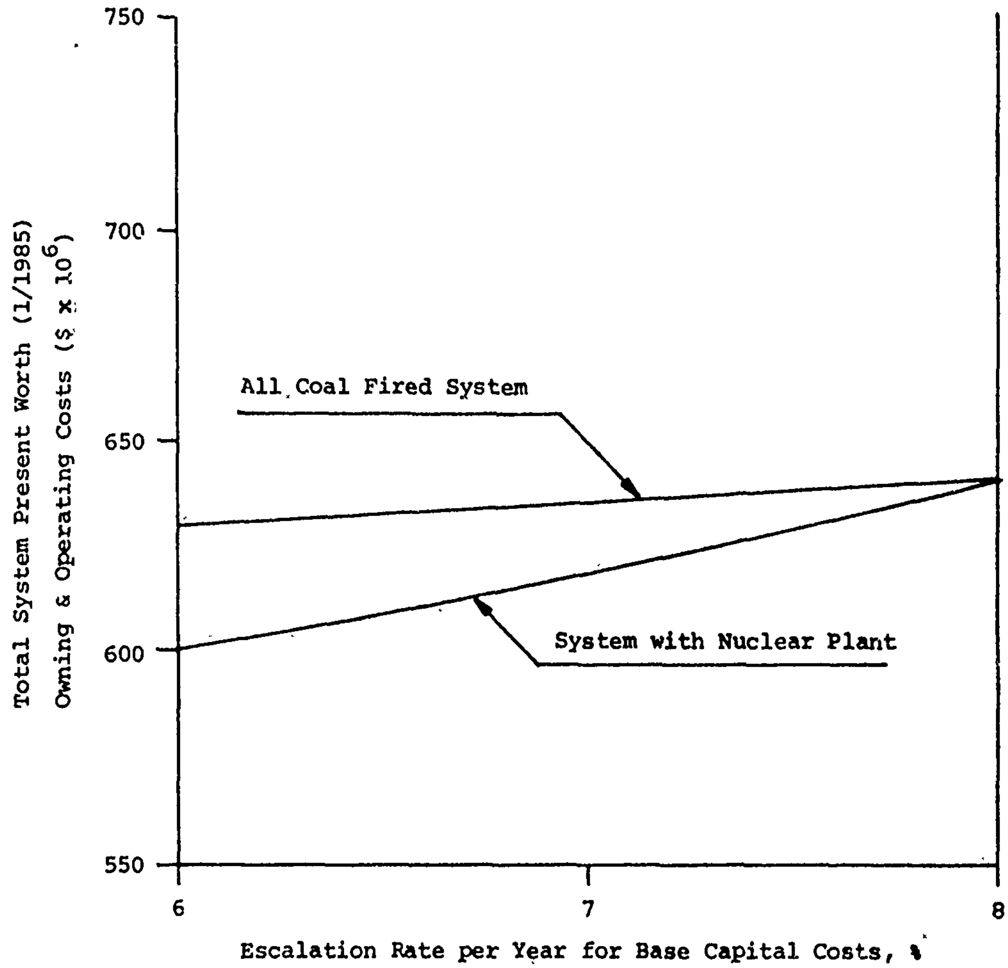


Figure 4.20 Effect of Escalation Rate for Base Capital Costs on Comparative Economics

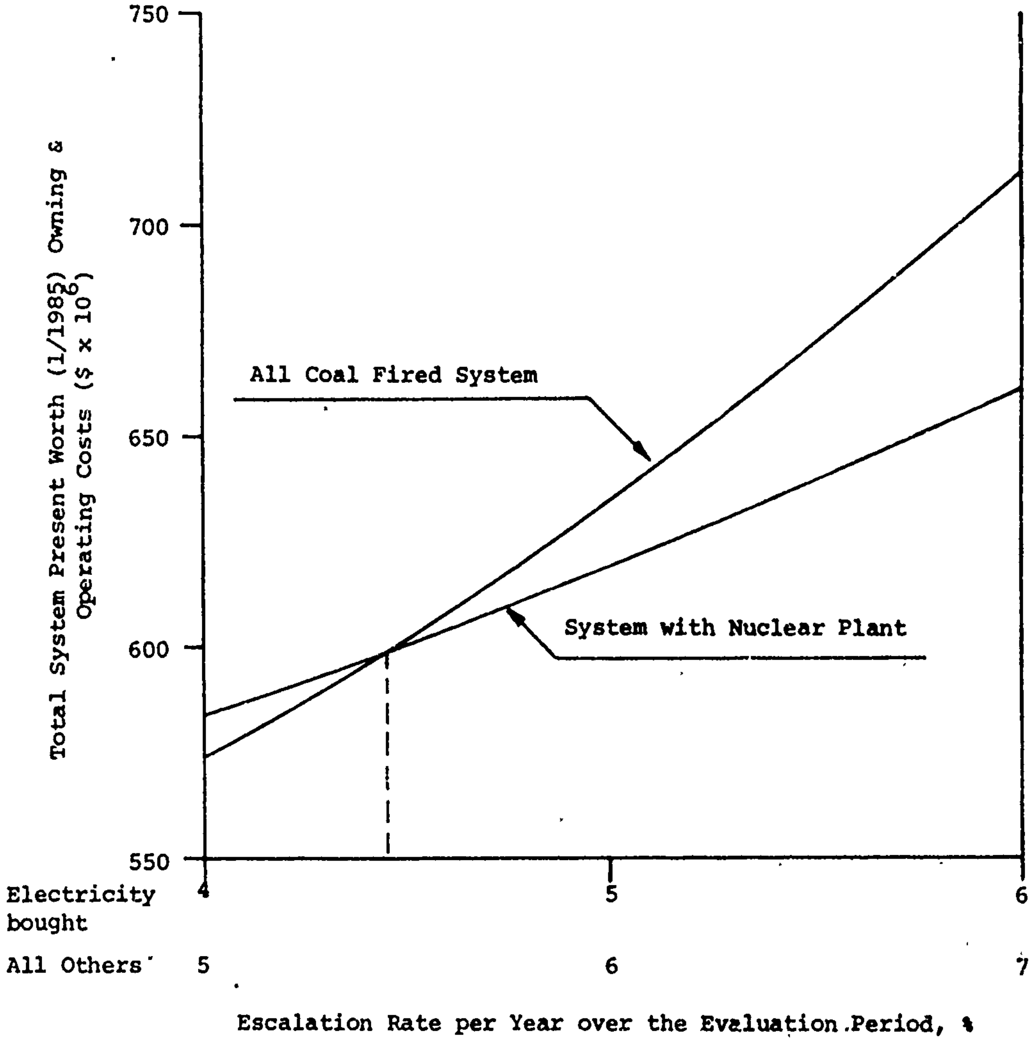


Figure 4.21 Effect of Esclation Rate over the Evaluation Period on Comparative Economics

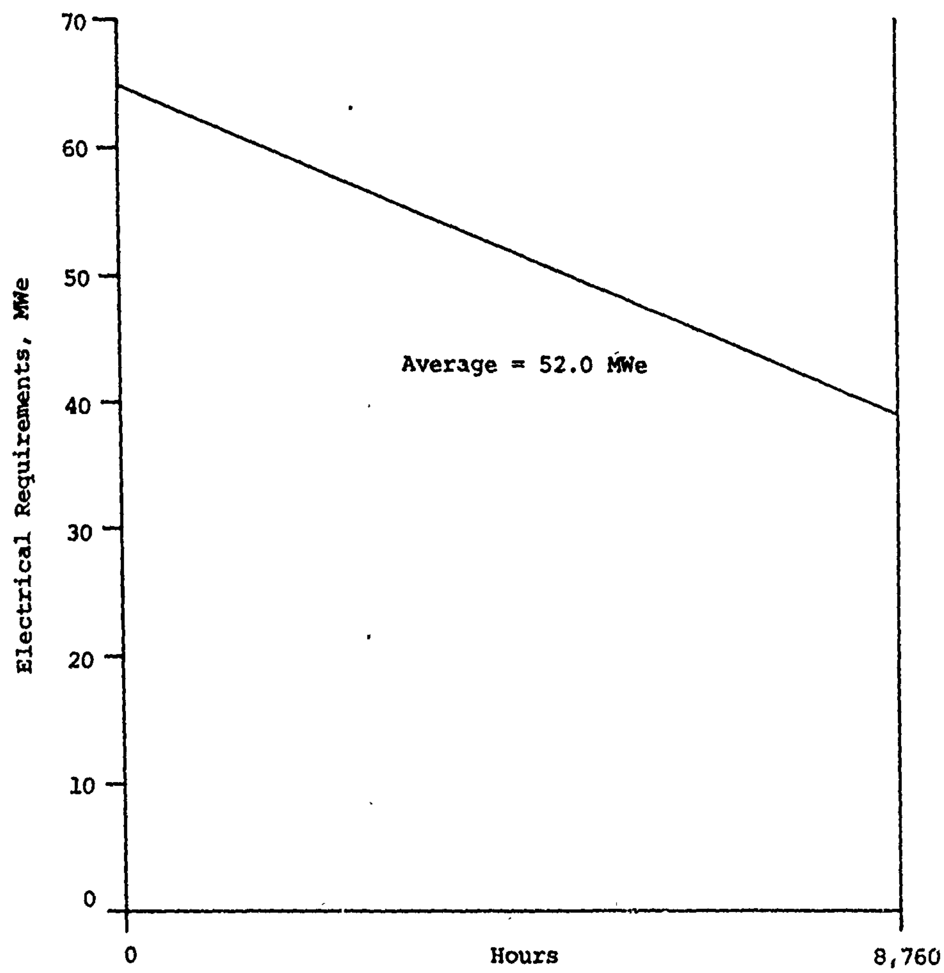


Figure 4.22 Yearly Load Duration Curve for Electrical Requirements Under Full Mobilization Operation

4.10 Economic Evaluation Based Upon Alternate Levels of Mobilization

The economic evaluation done so far was based upon the assumption that RAAP operates at an average of 45% (base case) of peak full mobilization. The optimum mix for the nuclear plant was determined to be an export steam capacity of 570,000 #/hr and a gross electrical capability of 30.0 MWe. The comparative economics of the system with nuclear plant vs. the all coal fired system was shown for the base case and for cases when RAAP operates at an average of 35% and 55% of peak full mobilization requirements. These later cases were evaluated keeping the same mix for the nuclear plant as that mentioned before. Thus, they represented the effects of uncertainty in predicting expected average usage of RAAP. In other words, they tried to answer the question: "Our best estimate for expected utilization is 45% and we will select all designs based upon this case. However, what happens if we were wrong and the expected utilization actually came out to be 35% or 55% ?". However, they did not answer, "What happens if the best estimate for utilization is revised ?". This situation will need a re-optimization of the nuclear plant mix and a comparative evaluation to be based upon the new optimum design.

Two such cases when RAAP is expected to operate at an average of 60% of peak full mobilization requirements and at full mobilization for the entire evaluation period, are evaluated in this section. The load duration curves shown in figures 4.22 and 4.23 are for the full mobilization case. They are based upon the assumption that the average load during the year is 80% of the peak load.

A series combination for the nuclear plant to produce electricity is assumed to be unacceptable because of deterioration in export steam conditions. A summary of the analysis for various parallel combinations is shown in Figure 4.24. For the 60% of peak full mobilization case, a mix with 20 to 25 MWe of gross electrical output seems to have some economic advantage over the all steam case. The advantage, however, is rather small and the recommended mix is all steam, which also reduces the capital investment requirements. For the full mobilization case, the optimum mix for the nuclear plant is clearly all steam. The main reason that the mix shifts to all steam is that at higher levels of mobilization, the nuclear plant (for 100% steam export) does not have much excess capacity from an operational stand point. This is in contrast to the situation for 45% of peak full mobilization case. In the later case, expected usage is substantially lower than the 100% steam export capacity of the nuclear plant.

Tables 4.13 and 4.14 summarize the economic evaluation of a nuclear system vs. a coal system for 60% of peak full mobilization and the full mobilization case respectively. For the 60% case, the nuclear system has a very significant economic advantage over the coal system. For the full mobilization case, the advantage is rather substantial in favor of the nuclear system.

Figure 4.25 is a plot of economic advantage of a nuclear system over a coal system, as a function of utilization of RAAP. The two systems break even at about 41% of peak full mobilization case. At higher levels of mobilization, the nuclear system has a progressively increasing economic advantage

over the coal system. The reverse is true for lower levels of mobilization.

Figure 4.26 gives the break-even period and the payback period for a nuclear system, as a function of utilization of RAAP. The computations are based upon an incremental basis with an all coal system. The payback period is the number of years of operation needed to recover the incremental investment in the nuclear system. The break-even period is the number of years of operation needed to recover the incremental investment and also, the associated interest charges for the nuclear system. The payback period is not recommended for use as a criteria but can only be used as a constraint.

It can be seen that the lowest break-even period for the nuclear system is about 12.5 years. This is the case when RAAP is expected to operate at full mobilization. For lower levels of mobilization, the break-even period is higher. Clearly, the nuclear system is a long term investment, with benefits strongly dependent upon the utilization of RAAP.

TABLE 4.13 TOTAL SYSTEM COMPARATIVE OWNING & OPERATING COSTS ($\$ \times 10^3$)

NUCLEAR VS. FOSSIL

RAAP OPERATES AT AN AVERAGE OF 60% OF PEAK FULL MOBILIZATION REQUIREMENTS OVER ENTIRE EVALUATION PERIOD (1985-2020)

	System With Nuclear Plant*	All Coal Fired System
Capital Costs		
Total Capital Investment (1/1985)	264,700	84,800
Annual Operating Costs		
Nuclear Fuel Costs	3,133	-
Boiler Fuel (coal) Costs	Base	16,044
Nuclear Plant O&M Costs	5,173	-
Boiler Plant O&M Costs	Base	6,785
Cost of Buying Electricity from Appalachian Power	2,485	Base
TOTAL ANNUAL OPERATING COSTS	10,791	22,829
Present Worth (1/1985) of Annual Operating Costs	210,100	456,600
TOTAL PRESENT WORTH COMPARATIVE OWNING & OPERATING COSTS (1/1985)	474,800	541,400

*The nuclear plant is designed for 100% steam export.

TABLE 4-14 TOTAL SYSTEM COMPARATIVE OWNING & OPERATING COSTS ($\$ \times 10^3$)

NUCLEAR VS. FOSSIL

RAAP OPERATES AT FUEL MOBILIZATION
OVER ENTIRE EVALUATION PERIOD (1985-2020)

	System with Nuclear Plant*	All Coal Fired System
Capital Costs		
Total Capital Investment (1/1985)	264,700	84,800
Annual Operating Costs		
Nuclear Fuel Costs	4,028	-
Boiler Fuel (coal) Costs	Base	20,597
Nuclear Plant O&M Costs	5,235	-
Boiler Plant O&M Costs	Base	8,711
Cost of Buying Electricity from Appalachian Power	3,150	Base
TOTAL ANNUAL OPERATING COSTS	12,413	29,308
Present Worth (1/1985) of Annual Operating Costs	241,000	586,200
TOTAL PRESENT WORTH COMPARATIVE OWNING & OPERATING COSTS (1/1985)	505,700	671,000

* The nuclear plant is designed for 100% steam export which will be the optimum mix under the particular situation.

4.11 Conclusions

The analysis and discussion presented in Section 4 leads to the following conclusions:

1. Economic characteristics of the nuclear system over the coal system is strongly dependent upon the expected utilization of RAAP. At 45% of peak full mobilization, the nuclear system has a slight economic advantage over the coal system. (Total present worth 1985 owning and operating costs of 619 Vs. 636 million dollars). At 60% of peak full mobilization, the nuclear system has a very significant economic advantage over the coal system. For the full mobilization case, the nuclear system has a substantial economic advantage over the coal system. (Total present worth 1985 owning and operating costs of $\$506 \times 10^6$ vs. $\$671 \times 10^6$). Clearly, the nuclear system's economic advantage over the coal system is increased with level of mobilization.

2. Parameters which can have a substantial effect on comparative economics are coal prices, base cost estimates for the nuclear plant, O&M costs for boiler plant with SO_2 removal system, availability factor for PE-CNSG and escalation rates for various operating costs over the evaluation period.

3. Parameters which can have a significant effect on comparative economics, are nuclear fuel costs, purchased electricity costs, plant life (evaluation period), nuclear plant O&M costs and escalation rate for base capital costs.

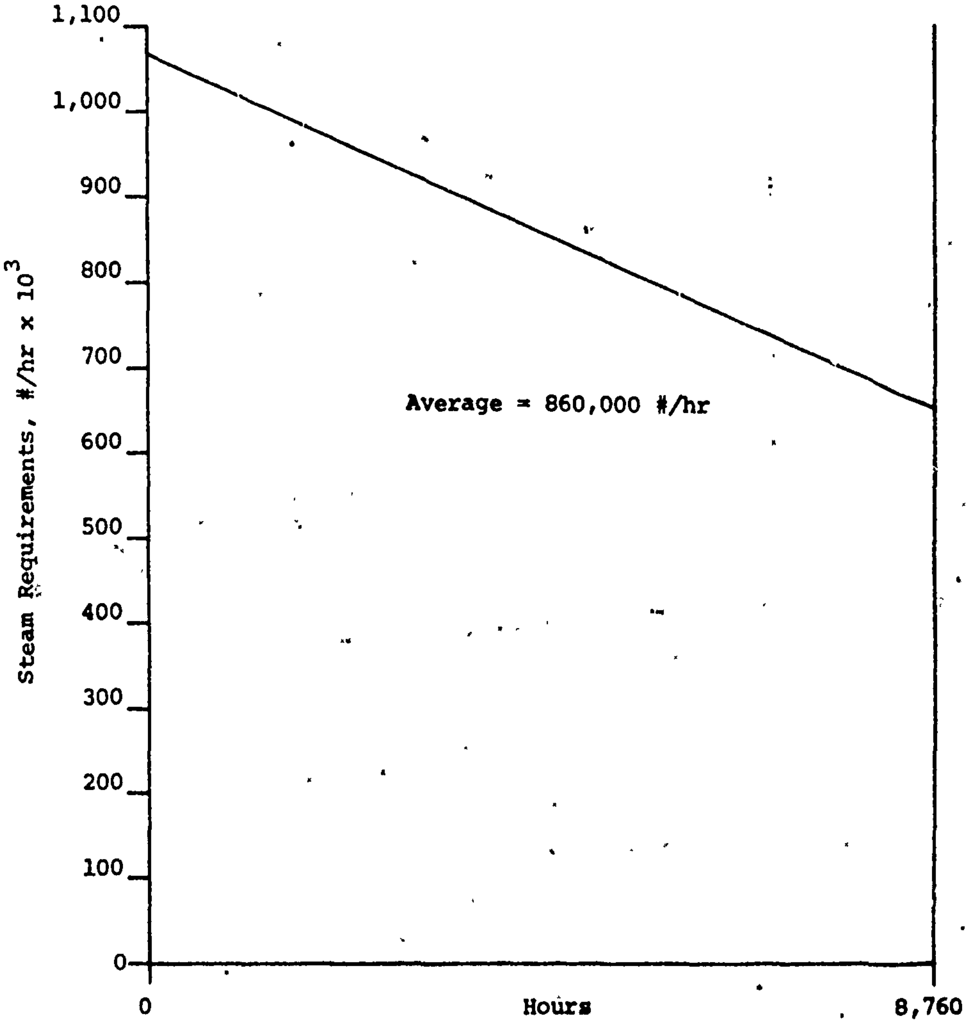


Figure 4.23 Yearly Load Duration Curve for Steam Requirements Under Full Mobilization Operation

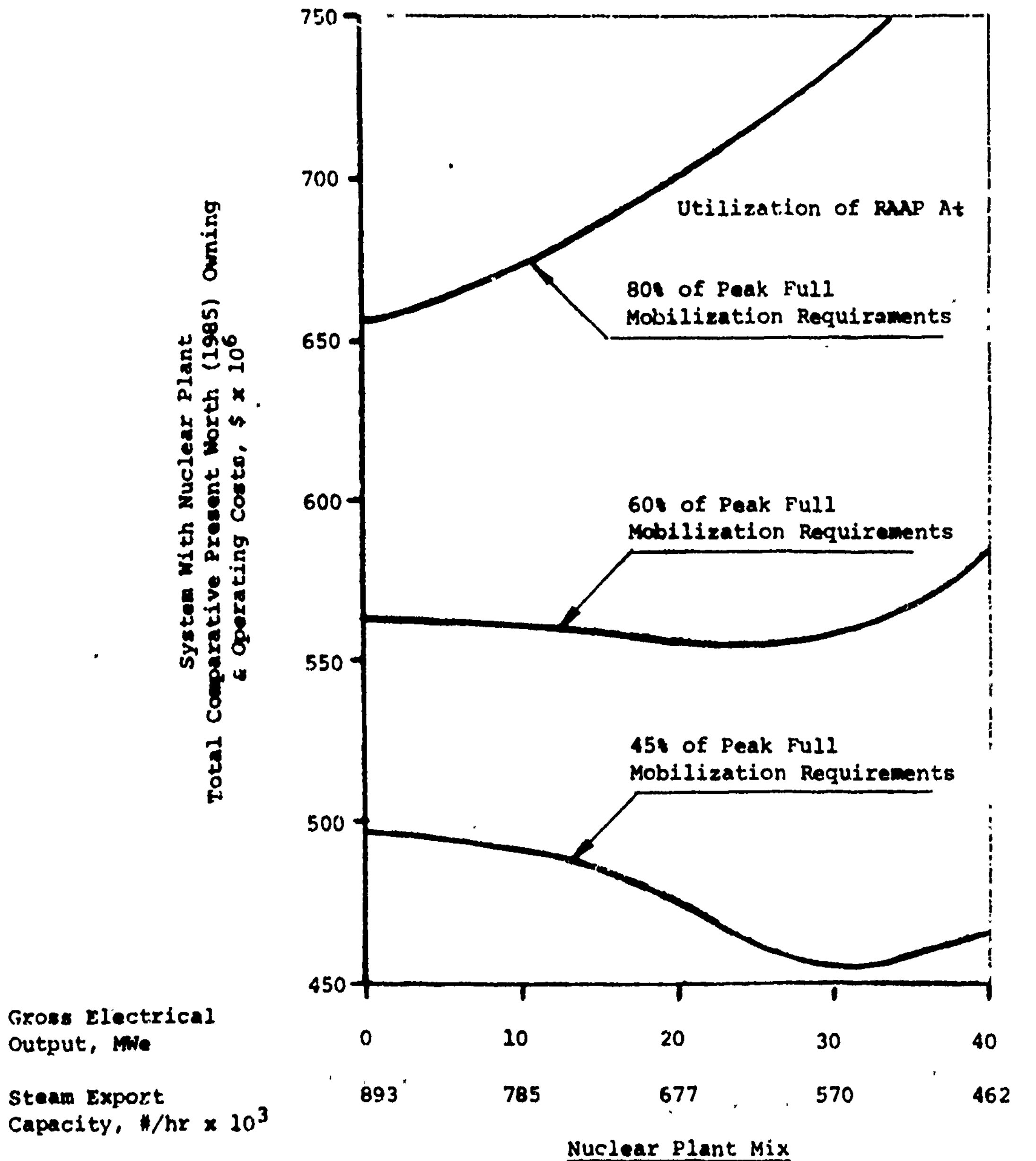


Figure 4.24 **Effect of Nuclear Plant Mix On Total System Owning & Operating Costs**

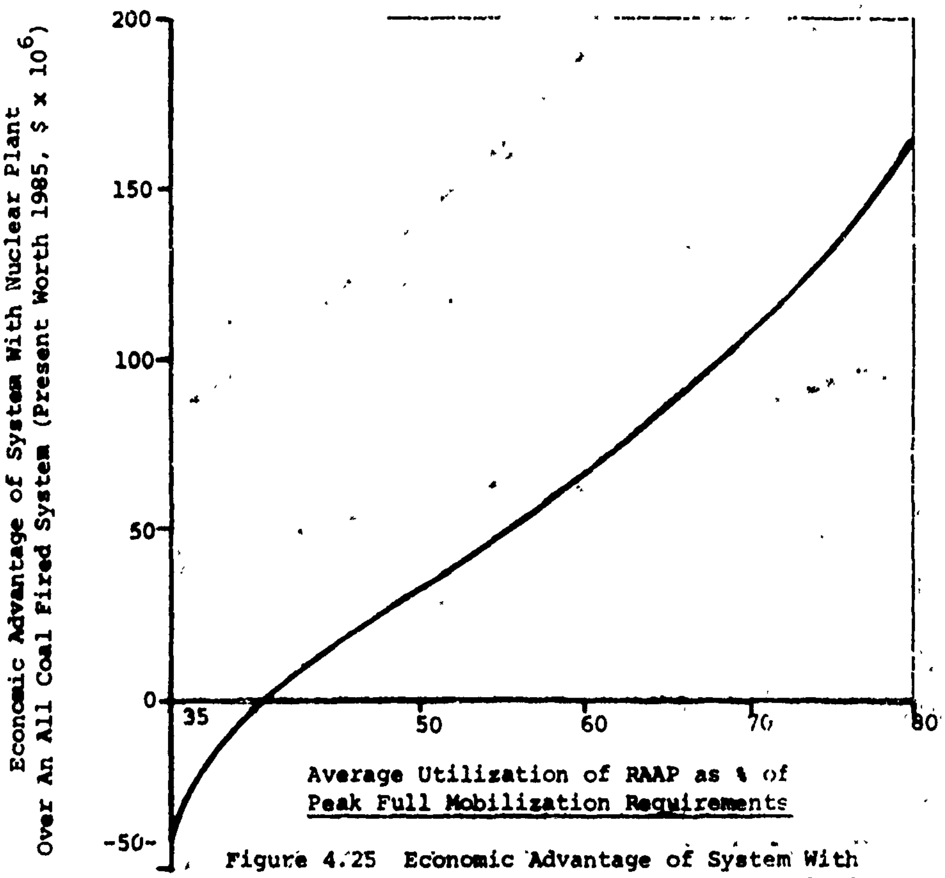
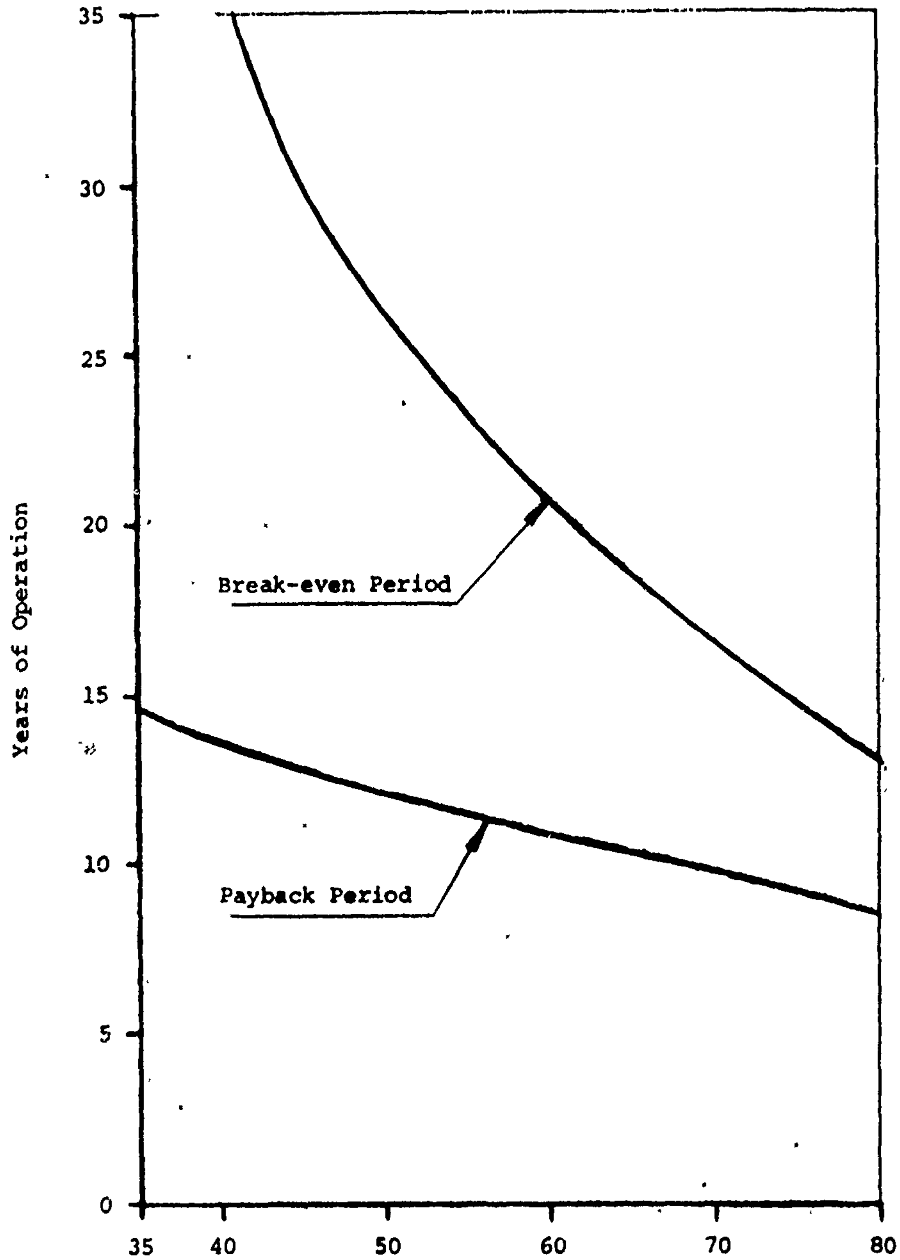


Figure 4.25 Economic Advantage of System With Nuclear Plant Over an All Coal Fired System, As a Function of Utilization of RAAP

NOTE: Average usage at 80% of peak full mobilization requirements represents full mobilization usage of RAAP.



Average Utilization of RAAP as % of Peak Full Mobilization Requirements

Figure 4.26 Payback and Break-even Periods For a System With Nuclear Plant (Computed on an Incremental Basis With an All Coal Fired System)

4. The economic evaluation presented here represents the situation for RAAP only, and does not represent a generalized evaluation of the PE-CNSG vs a coal fired plant. Structural characteristics of RAAP such as the existence of extraction turbines and associated equipment, building, etc., mean that the coal fired system is not penalized for associated capital costs. Also, substantial requirements for low pressure (40 PSI) steam means that a significant amount of low cost electricity can be generated (with the use of extraction turbines) in case of an all coal fired system. Furthermore, the amount of total steam requirements and the relatively large capacity of the PE-CNSG adversely affect the system with nuclear plant in terms of reliability considerations as well as the level of utilization which can be achieved for the PE-CNSG.

5. The optimum mix for the nuclear plant is a function of utilization of RAAP (Figure 4.24). For the case when RAAP is expected to operate at an average of 45% of peak full mobilization, the optimum mix is a gross electrical output of 30 MWe and a steam export capacity of 570,000 #/hr. For the 60% of peak full mobilization case, a mix with 20 to 25 MWe of gross electrical output seems to have some advantage over the all steam case. The advantage, however, is rather small and the recommended mix is all steam, which also reduces the capital investment requirements. For the full mobilization case, the optimum mix is all steam.

6. For each of the three optimum cases described above, a single 500,000 #/hr generating capacity coal fired boiler is used as a

backup for meeting steam requirements. This will provide reliability equivalent to that of a coal system with three new boilers, each with a generating capacity of 250,000 #/hr. It is possible that the size of the backup for nuclear plant can be reduced depending upon the exact nature of tradeoff between reliability and capital costs.

7. Reactor scram can result in loss of steam supply to RAAP with, possibly, insufficient warning time and should be given further consideration. One way to alleviate the problem is to have the backup boiler in hot shut-down. This, however, can be expensive and the costs should be carefully evaluated against the benefits achieved.

   For the base case evaluated in this report, it should be noted, however, that at times of high levels of mobilization, some of the boiler facilities will also be active in meeting total steam requirements. At such times, boiler output can be immediately increased (to a certain extent) if a reactor scram does occur. This will tend to reduce the costs associated with a reactor scram.

   In times of low levels of mobilization, the nuclear plant might be the only unit providing steam requirements. A reactor scram in such times, might mean a complete loss of steam supply to RAAP. However, the fact that RAAP is operating at low capacity might mean that the cost of reactor scram will not be substantial.

8. The order of priority for meeting steam requirements (including 40 PSI steam) is nuclear plant, boilers in conjunction with extraction turbines and boilers alone. For meeting electrical requirements, the order of priority is nuclear plant, electricity available from the operation of extraction turbines, Appalachian Power and condensing turbines. (The desirability of Appalachian Power over condensing turbines depends upon the particular situation).

APPENDIX 1

ANALYSIS OF SYSTEM OPERATION

APPENDIX 1

ANALYSIS OF SYSTEM OPERATION

This section shows sample calculations for average yearly operating data for the system with nuclear plant and an all coal fired system. Load duration curves used are corresponding to the base set of data when the expected average utilization of RAAP is at 45% of peak full mobilization requirements. Operating data are estimated so as to optimize overall system operation, as described in Section 4.7, titled, "Strategy for System Operation".

System with Nuclear Plant

Yearly operating data are estimated for system with nuclear plant having an optimum mix of 570,000 #/hr of steam export capacity and 23 MWe of net electrical output.

In Figure A1-1, AB is the yearly load duration curve for steam requirements. EF corresponds to 570,000 #/hr, the steam export capacity of the nuclear plant. If the nuclear plant was available all the time, the amount of steam exported per year by the nuclear plant will be given by the area BCDEF. Based upon an availability factor of 85% (for steam export), it is clear that

Steam exported from nuclear plant = (Area BCDEF)(0.85) = 3,518 x 10^6 #/yr

It should be pointed out that part of the steam exported from nuclear plant goes for meeting 40 psi steam requirements of RAAP. The amount of nuclear fuel used is the same regardless of whether the steam exported is eventually used as 40 psi steam or other steam. Thus, there is no need to break down the steam exported from nuclear plant into its 40 psi and other components.

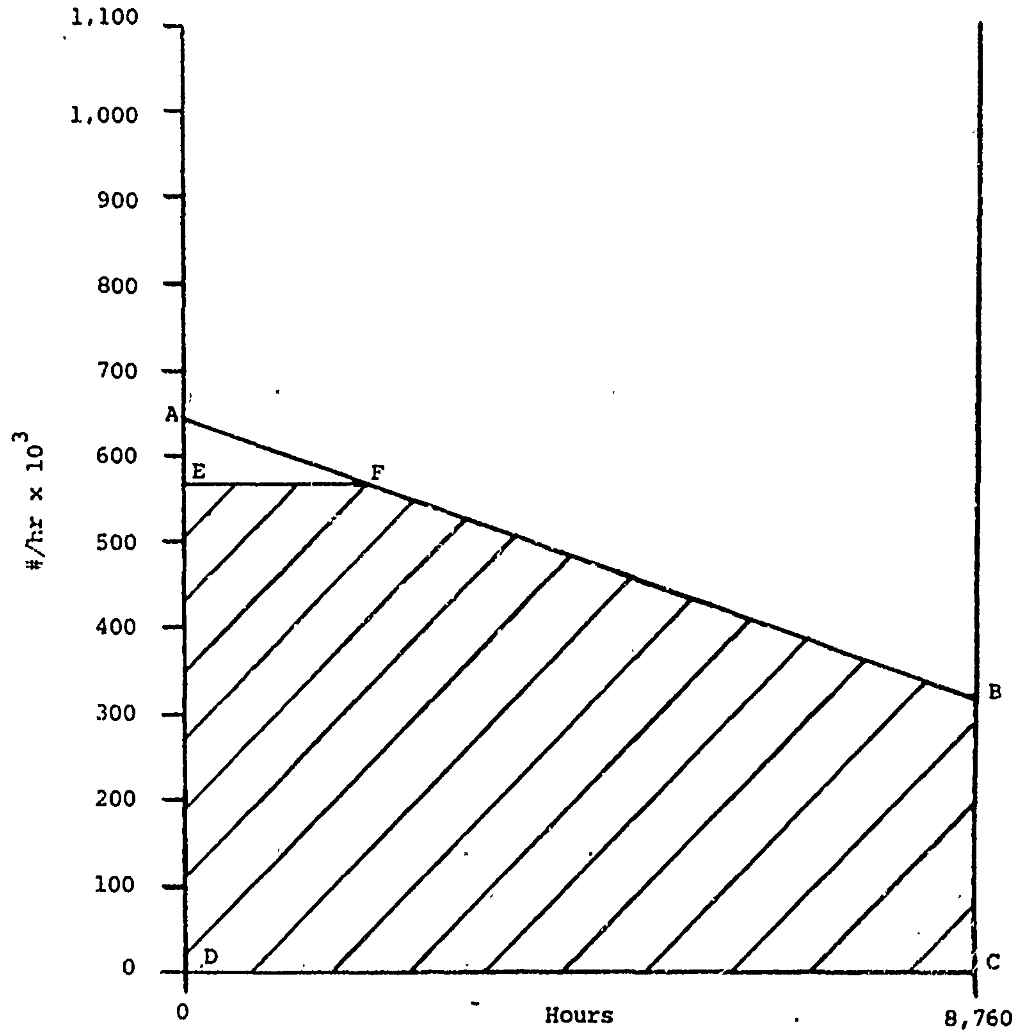


Figure A1-1 Yearly Load Duration Curve for Steam Requirements

Expected Average Utilization of RAAP at

45% of Peak Full Mobilization Requirements

The balance of steam requirements must be met by exporting steam from fossil boilers. The steam exported from such boilers is

$= (480{,}000 \times 8{,}760 - 3{,}518 \times 10^6)$

$= 687 \times 10^6$ #/yr.

Part of steam exported by boiler plants is 40 psi steam. This can be important because the amount of electricity generated by the operation of extraction turbines is dependent upon the amount of 40 psi steam exported. Since 25% of process steam requirements are 40 psi, the amount of 40 psi steam exported by boiler plants is

$= 687 \times 10^6 \times 0.25 = 172 \times 10^6$ #/yr

(In reality, all of steam requirements shown by area AEF can be met by 40 psi steam exported from the boiler plants. Thus 172×10^6 #/yr of 40 psi steam exported from boiler plants is an underestimation. The effect, however, is insignificant as far as the system with nuclear plant is concerned.)

In case of electrical requirements, Figure A1-2 shows AB as the yearly load duration curve. EF corresponds to 23 MWe, the net electrical capacity of the nuclear plant. Based upon an availability factor of 83% for electricity export,

Electricity exported by the nuclear plant = (Area BCDEF)(0.83) = 166×10^6 kWhr/yr

Electricity exported by boiler plants (net of auxiliary power and SO_2 removal system requirements) while exporting 172×10^6 #/yr of 40 psi is small and is neglected. Thus, the balance of electrical requirements must be met by purchased power.

Electricity purchased = $(30{,}000 \times 8{,}760 - 166 \times 10^6) = 97 \times 10^6$ kWhr/yr

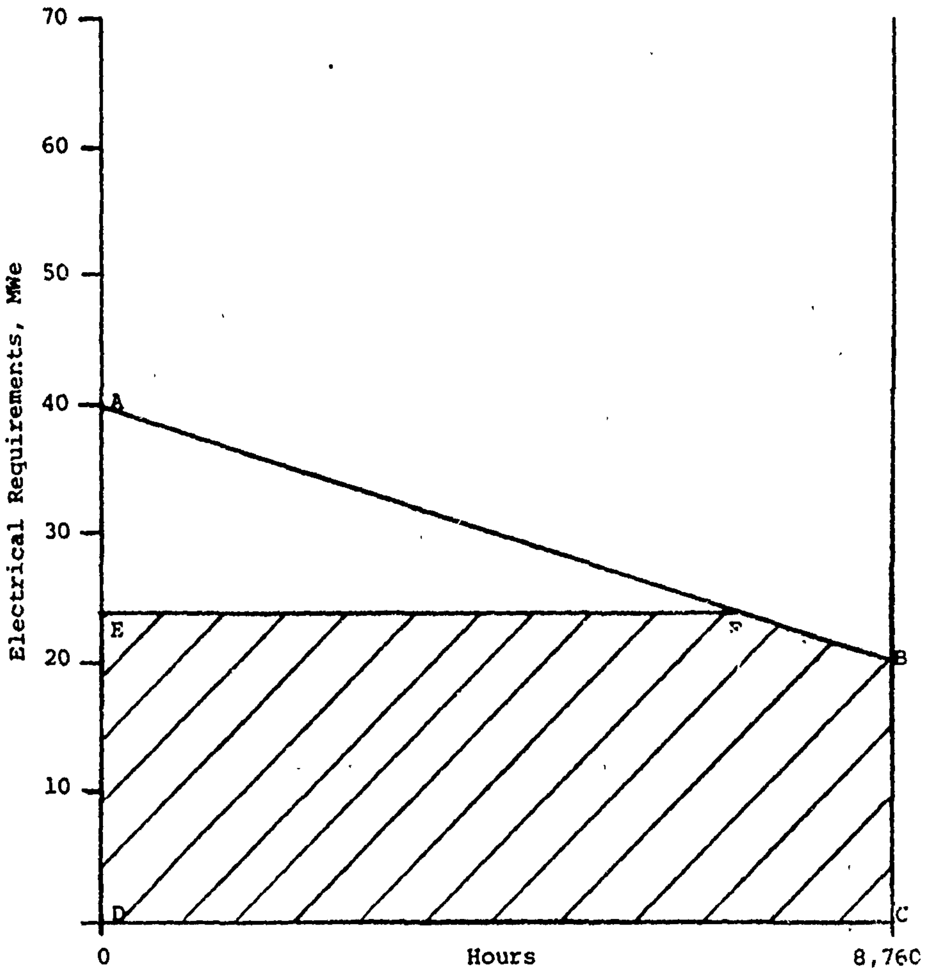


Figure A1-2 Yearly Load Duration Curve for Electrical Requirements

Expected Average Utilization of RAAP at

45% of Peak Full Mobilization Requirements

The amount of nuclear fuel used for exporting $3,518 \times 10^6$ #/yr of steam is $= \frac{3,518 \times 10^6}{893,000} \times 313,000 \times 3,413$

$= 4,207 \times 10^9$ Btu/yr

The amount of nuclear fuel used for exporting 166×10^6 kWhr of electricity is estimated by multiplying corresponding gross electrical output by gross heat rate. Amount of nuclear fuel used for exporting 166×10^6 kWhr/yr of electricity is $= (166 \times 10^6 + 7,000 \times 8,760 \times 0.85) \times 12,892 = 2,810 \times 10^9$ Btu/yr.

Total nuclear fuel used for exporting both steam and electricity is

$= (4,207 + 2,810) \times 10^9 = 7,017 \times 10^9$ Btu/yr

The overall capacity factor for the CNSG is the ratio of actual thermal output per year to the thermal output if the CNSG were operating for the whole year at its rated output.

$$\text{Overall capacity factor for CNSG} = \frac{7,017 \times 10^9}{313,000 \times 3,413 \times 8,760} \approx 0.75$$

Btu's of coal used is dependent upon the amount of 40 psi and other steam exported from boiler plants.

Btu's of coal used $= 172 \times 10^6 \times 1,551 + (687-172) \times 10^6 \times 1,342$

$= 957 \times 10^9$ Btu/yr

All Coal Fired System

In case of an all coal fired system, all steam requirements are met by exporting steam from boiler facilities. The amount of 40 psi steam exported is important because substantial amounts of electricity can be generated while exporting 40 psi steam.

Total steam exported by boiler facilities $= 480,000 \times 8,760 \simeq 4,205 \times 10^6$ #/yr

40 psi steam requirements are equal to steam for building heat plus 25% of process steam requirements.

40 psi steam exported = $263 \times 10^6 + (4,205 - 263) \times 10^6 \times 0.25$

$= 1,248 \times 10^6$ #/yr

Other steam exported = $(4,205 - 1,248) \times 10^6 = 2,957 \times 10^6$ #/yr

Btu's of coal used = $(1,248 \times 1,551 + 2,957 \times 1,342) \times 10^6$

$= 5,904 \times 10^9$ Btu /yr.

Gross electrical output of extraction turbines associated with exporting $1,248 \times 10^6$ #/yr of 40 psi steam is $= \frac{1,248 \times 10^6}{109,000} \times 6,000$

$= 69 \times 10^6$ kWhr/yr

Auxiliary power requirements for boiler facilities = $5,000 \times 8,760$

$= 44 \times 10^6$ kWhr/yr

Net electricity available from the operation of extraction turbines

$= (69 - 44) \times 10^6 = 25 \times 10^6$ kWhr/yr

The rest of the electrical requirements are met from purchased power.

Electricity purchased = $30,000 \times 8,760 - 25 \times 10^6 = 238 \times 10^6$ kWhr/yr

APPENDIX 2

RATE SCHEDULE FOR

PURCHASED POWER

American Electric Power System

APPALACHIAN POWER CO.

Post Office Box 999, Pulaski, Virginia 24301
Telephone: area code 703 - 980-1140

November 6, 1975

United Engineers and Constructors
1401 Arch Street
Philadelphia, Pennsylvania 19105

Attn: Mr. D. E. Cabrilla

Gentlemen:

Mr. Anthony Nida, Corps of Engineers, has requested that we provide you with a copy of Schedule L.C.P. (Large Capacity Power) on which the Radford Army Ammunition Plant is presently being billed for electric service.

Yours very truly,

B B McCall

B. B. McCall
Customer Services Manager

BBMcC:n
Enclosure

SCHEDULE L.C.P.
(Large Capacity Power)

AVAILABILITY OF SERVICE

Available for power service. Customers shall contract for a definite amount of electrical capacity in kiloWatts which shall be sufficient to meet normal maximum requirements, but in no case shall the capacity contracted for be less than 1,000-KW. The Company may not be required to supply capacity in excess of that contracted for except by mutual agreement. Contracts will be made in multiples of 100-KW.

MONTHLY RATE

Primary Portion:
First 1,000-KW of monthly billing demand .... $7.663 per KW
Next 3,000-KW of monthly billing demand .... $7.086 per KW
All over 4,000-KW of monthly billing demand .... $6.486 per KW
The customer shall be allowed 315-KWH for each KW of monthly billing demand billed hereunder.

Secondary Portion:
Energy in excess of 315-KWH per KW of monthly billing demand $0.01515 per KWH

Reactive Demand Charge:
For each KILOVAR of lagging reactive demand in excess of 50% of the KW of monthly billing demand .... $0.29 per KVAR

RATE ADJUSTMENT

In any monthly period when metered KWH are less than 315-KWH per KW of monthly billing demand, the customer shall receive a credit on such deficiency in KWH at a rate of $0.01039 per KWH.

MEASUREMENT AND DETERMINATION OF DEMAND

The billing demand in KW shall be taken each month as the highest single 30-minute integrated peak in KW as registered during the month by a demand meter or indicator, or, at the Company's option, as the highest registration of a thermal type demand meter or indicator.

The reactive demand in KVAR shall be taken each month as the highest single 30-minute integrated peak in KVAR as registered during the month by a demand meter or indicator, or, at the Company's option, as the highest registration of a thermal type demand meter or indicator.

DELIVERY VOLTAGE

The rate set forth in this Schedule is based upon the delivery and measurement of energy at standard voltages established by the Company of not less than 2,300 volts or more than approximately 14,000 volts. Where service is delivered from lines operated at a normal voltage of approximately 14,000 volts or less, service hereunder shall be delivered and measured at the primary voltage of the said line.

EQUIPMENT SUPPLIED BY CUSTOMER

Where the customer owns, operates and maintains all equipment and apparatus beyond the delivery point of service which are necessary for receiving and purchasing electric energy at the primary voltage of lines operating at 33,000 volts or over, bills hereunder shall be subject to a credit of $0.29 per KW of monthly billing demand.

FUEL ADJUSTMENT CLAUSE

Bills computed according to the rates set forth herein will be increased or decreased by a Fuel Adjustment Factor per KWH calculated in compliance with the Fuel Adjustment Clause contained in Sheet No. 4 of this Tariff.

Issued: May 5, 1975 Effective: May 9, 1975

Issued By
John W. Vaughan, Executive Vice President
Roanoke, Virginia

SCHEDULE L.C.P. (Cont.)
(Large Capacity Power)

MINIMUM CHARGE

This Schedule is subject to a minimum monthly charge equal to: 60% of customer's contract capacity or 1,000-KW (whichever is greater) multiplied by $1.53 per KW, subject to (a) charges in accordance with the Fuel Adjustment Clause for actual KWH used, and (b) adjustment for lagging reactive demand at the rate of $0.29 for each KVAR in excess of 50% of: 60% of customer's contract capacity or 1,000-KW (whichever is greater).

PAYMENT

Bills are due and payable at the main or branch offices of the Company within twenty (20) days of the mailing date.

TERM

Variable, but not less than one year.

SPECIAL TERMS AND CONDITIONS

See Sheets No. 3-1, 3-2, 3-3, 3-4 and 3-5 for Terms and Conditions of Service.

This Schedule is available for resale service to legitimate electric public utilities and to mining and industrial customers who furnish service to company-owned camps or villages where living quarters are rented to employees and where the customer purchases power at a single point for his power and camp requirements.

This Schedule is available to customers having other sources of electric energy supply.

Issued: May 5, 1975 Effective: May 9, 1975

Issued By
John W. Vaughan, Executive Vice President
Roanoke, Virginia

APPENDIX 3

NUCLEAR FUEL COSTS

APPENDIX 3

NUCLEAR FUEL COSTS

A very preliminary analysis was carried out in order to arrive at a fuel cycle cost for the Consolidated Nuclear Steam Generator (CNSG) plant for 1986 operation.

The results are based on UE&C data and experience for central station nuclear power plant costs extrapolated for the particular situation at hand.

For the purpose of arriving at an overall fuel cycle cost number in mills/kWhr, the plant was assumed to have an electrical rating of 100 MWe.

The NRC Regulatory Guide 1.83 stipulates steam generator tube inspection at intervals not to exceed 20 months. An 18 month refueling period was therefore chosen.

Feed enrichment was assumed to be 5.08% w of U^{235} and discharge enrichment at 3% w U^{235}.

Fuel burning was assumed at 33727 MWD/MTV. Based on the normal U^{235} concentration of 0.711% in natural uranium and a tails enrichment of 0.25%, we arrive at the equivalent of 116.6 MBTU per 1 lb of U_3O_8.

An increase therefore in the price of yellowcake of $1/lb will result in a unit energy cost of 0.0976 mills/kWhr for a 30% plant efficiency.

An additional consideration is the unit cost increase in securing the ore and the various other processes because of a reduction in the amount of ore and services required for a 100 MWe versus a 1000 MWe plant. Depending

on DOD purchasing policies, this consideration may not apply. However, for purposes of consistency, a 10% penalty was applied to ore costs and fabrication costs.

Item	Unit Cost	Mills/kWh
U_3O_8 Ore	$ 70/lb	6.8
Conversion	$ 10/kg	0.3
Enrichment	$132/SWU	2.2
Fabrication	$220/kg	1.0
Shipping	$ 50/kg	0.2
Reprocessing & Waste	$180/kg	0.8
		11.3
Credit*		-5.1
Grand Total		6.2

Converting to ¢/MBTU (6.2) (9.523) = 59.0 ¢/MBTU

The 59 C/MBtu is a 1986 cost. For 1985, the fuel costs can be taken as 55 ¢/MBTU

*Based on 3% w U^{235} discharge enrichment and 8% escalation.

APPENDIX 4

LICENSING FEES

APPENDIX 4

LICENSING FEES

Licensing and materials fees currently paid by utilities as per 10 CFR 170 are shown in Table 1 for the 313 MWt CNSG power plant. However, these fees are currently under review for amendment and it is expected that some change similar to the proposed revision of license fee schedules (as shown in Table 2) will be adopted prior to the proposed 1985 operation of the CNSG.

Briefly, the proposed changes entail the following:

(1) Distinction between custom plant applications, manufacturing license applications, reference plant applications, and duplicate plant applications.

(2) Establish an application fee for operating licenses.

(3) Establish an installment plan for payment of application fees.

(4) Delete the annual fee for the facility.

(5) Delete the annual fee for materials license.

(6) Establish fees for inspection of facilities as shown in Table 2.

It should be noted that for a 313 MWt power reactor, the current annual fees amount to approximately $105,395, and there is no fee for inspection of facilities. Under the proposed rule changes, there would be no annual fees, but there would be a charge of $12,096 for a routine inspection, which for a power reactor in operation today averages about 20 inspections per year. Any further inspections or audits would be additive. This proposed change is obviously the most significant and costly, since it affects the operating costs over the life of the plant and could vary greatly from year to year.

Table 1

Licensing Fees
(Currently in Effect)

	Application	Annual Fee
Application For Construction Permit	$125,000	
Construction Permit Fee	303,210*	
Operating License Fee	307,905*	
Materials License Fee	85,000*	$ 85,000*
Annual Fee	--	20,345*
	$821,115	$105,345

*313 MWt Power Plant

Table 2

Licensing Fees
(Proposed Changes to 10 CFR Part 170)

	Custom Plant	Duplicate Plant	Annual Fees
Licensing			
Application for Construction Permit	$125,000	$125,000	
Construction Permit Fee	51,958*	41,629*	
Application For Operating License	125,000	125,000	
Operating License Fee	63,539*	50,706*	
Materials License Fee	61,522	61,522	0
Annual Fee	0	0	[illegible]
**Routine Inspections (Avg. 20/yr.)	0	0	241,920
	$427,019	$403,857	$241,920

*313 MWt Power Plant

**Fees For Inspection:

Routine	$12,096
Incident	6,624
Enforcement	11,016
Management Audit	44,064

APPENDIX 5

CONSTRUCTION SCHEDULE

APPENDIX 5

CONSTRUCTION SCHEDULE

A construction schedule for the PE-CNSG developed for RAAP in this study has been prepared; which takes into account the specific requirements of the site and the steam and electrical distribution systems also developed in the study.

The basis for the RAAP schedule has been the schedules previously developed in reference 3.0-1 (Chapter 3).

Although the site and site requirements have necessitated modifications to the previous schedules, the fundamental basis for the schedule remains the specific features of the PE-CNSG that allow certain time-saving construction techniques to be utilized.

The details of these techniques can be found in reference 3.0-1; but a brief summary of the key methods is as follows:

(1) The bottom portion of the PE-CNSG containment structure* (up to and including the reactor vessel support structure) will be shop-fabricated and stress relieved.

(2) An ultra-heavy lifting device with a capacity of 300 tons to a radius of 150 ft., and with discending capacities to a maximum 270 ft. radius, would be used to set the containment, reactor vessel (255 tons) and other major pieces of equipment.

---

*This is a steel structure 38 ft. in diameter and 64 ft. high, with a base consisting of 4-inch thick steel plate. The reactor vessel support pedestal is mounted on the base.

The effects of the manufacturing time span required to fabricate the PE-CNSG NSSS specific lead times for the essential NSSS components (forgings, etc.), are not part of the construction schedule used for the purposes of this report, but can be found in ref. 3.0-1. However, it should be noted that the critical path of the schedule occurs through reactor fabrication, delivery, and installation due to the long lead time relative to other plant components. The construction schedule has been developed based upon completing as much reactor service building structural work prior to setting the reactor vessel as possible. A bar chart schedule, Figure A5-1, shows the major planned construction sequences of the PE-CNSG plant proper and the off-site items such as the steam distribution piping and the 6.9 KV transmission line.

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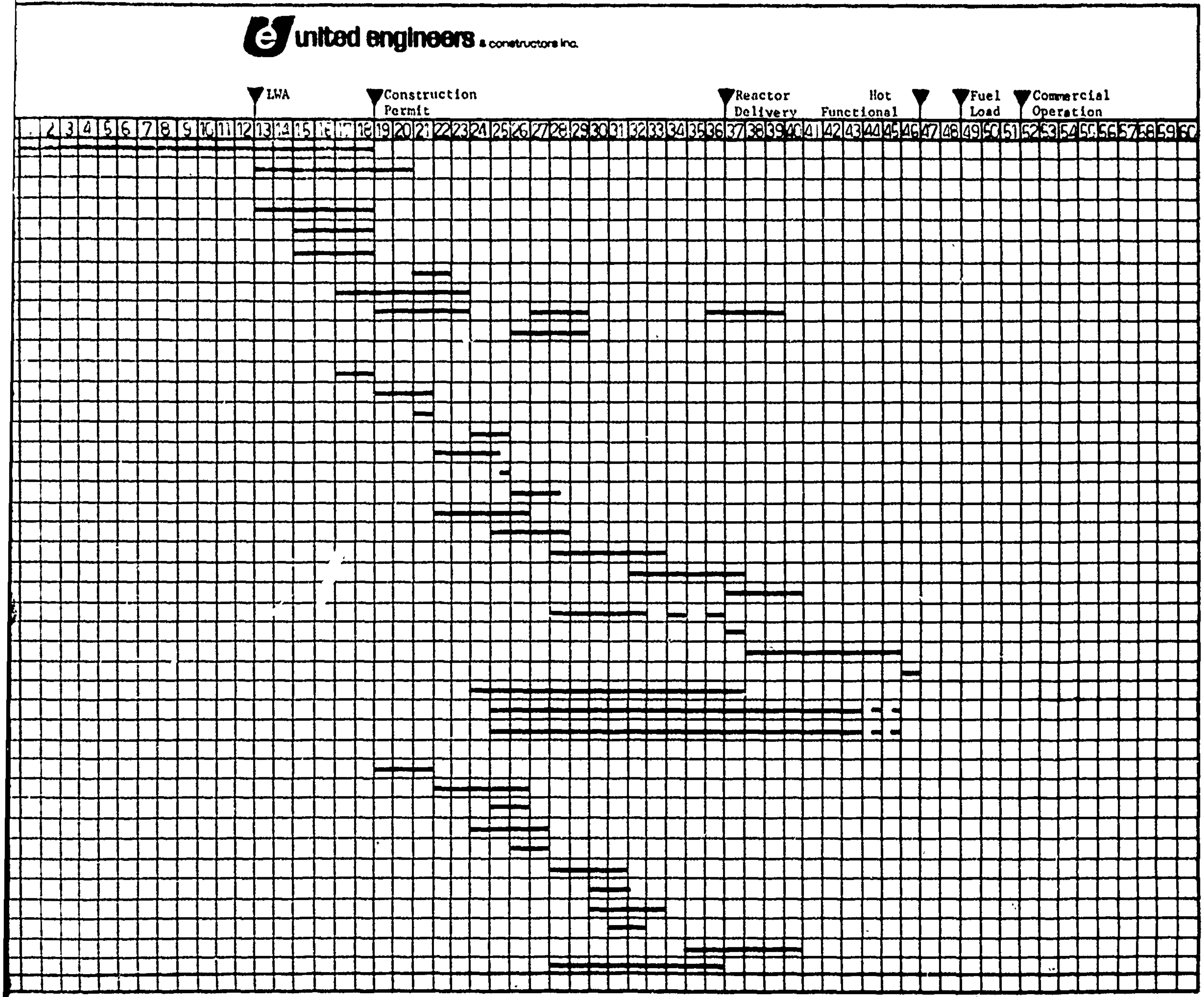
LWA

Construction Permit

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Licensing																												
Off-Site Railroad																												
Site Work																												
Clear Grub & Excavation																												
Temporary Facilities																												
Roads, Fencing & Parking																												
Railroad																												
Yard Piping																												
Circulating Water Piping																												
Service Water Piping																												
Reactor Service Building																												
Excavation																												
Base Mat - El 0'0"																												
4" Base Plate w/Stubs & Machined Disc																												
Piping Tunnel																												
Set Containment Vessel Balance																												
Primary Containment Air Test																												
Install Compressable Material																												
Concrete to El 26'																												
Concrete to El 46'																												
Concrete to El 89'																												
Erect Structural Steel & Cranes																												
Concrete to El 140' & Roof																												
Containment Internal Work																												
Set Reactor Vessel & Insulate																												
Vessel Internal Work & Hydro																												
Final Containment Pressure Tests																												
Install Mechanical Equipment																												
Install Electrical, I&C																												
Install Piping																												
Turbine Building & Reboilers																												
Excavation																												
T-G Mat & Pedestal																												
Reboiler Foundation																												
Concrete to Grade																												
Floor Slab & Grade																												
Erect Structural Steel, Crane & Monorails																												
Interior Concrete Slabs																												
Erect Siding & Roof																												
Erect Condenser (Shop Tubed)																												
Erect Turbine-Generator																												
Install Mechanical Equipment																												

PRELIMINARY



CONSTRUCTION SCHEDULE
PE-CNSG PLANT
FOR
DEPT OF THE ARMY
RADFORD ARSENAL
RADFORD VIRGINIA

FIGURE A5-1
PAGE 1 OF 3

4-15-76

PRELIMINARY

2

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LWA (month 13) — Construction Permit (month 19)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
Turbine Building & Reboilers																																			
Install Electrical, I&C																																			
Install Piping																																			
Turbine Service Building																																			
Concrete Slab & Footings																																			
Erect Structural Steel																																			
Interior Concrete Slabs																																			
Erect Siding & Roof																																			
Install Mechanical Equipment																																			
Electrical, I&C																																			
Install Piping																																			
Control Building																																			
Erect Concrete Structure																																			
Interior Concrete Slabs																																			
Install Roof																																			
Install Equipment & HVAC																																			
Electrical, I&C																																			
Install Piping																																			
Diesel Generator Building																																			
Erect Concrete Structure																																			
Install Mechanical Equipment																																			
Electrical, I&C																																			
Install Piping																																			
Diesel FO Tank Enclosure																																			
Concrete Slab & Walls to Grade																																			
Install Tanks																																			
Concrete Lid																																			
Install Electrical, I&C																																			
Install Piping																																			
Administration Building																																			
Concrete Grade Slab & Footings																																			
Erect Siding & Roof																																			
Install Interior																																			
Service Water Intake Structure																																			
Transformer Foundations																																			
Set Transformers																																			
Field Erected Tanks																																			
Service Water Cooling Tower																																			
Condenser Cooling Tower																																			
Start-up Activities																																			

PRELIMINARY

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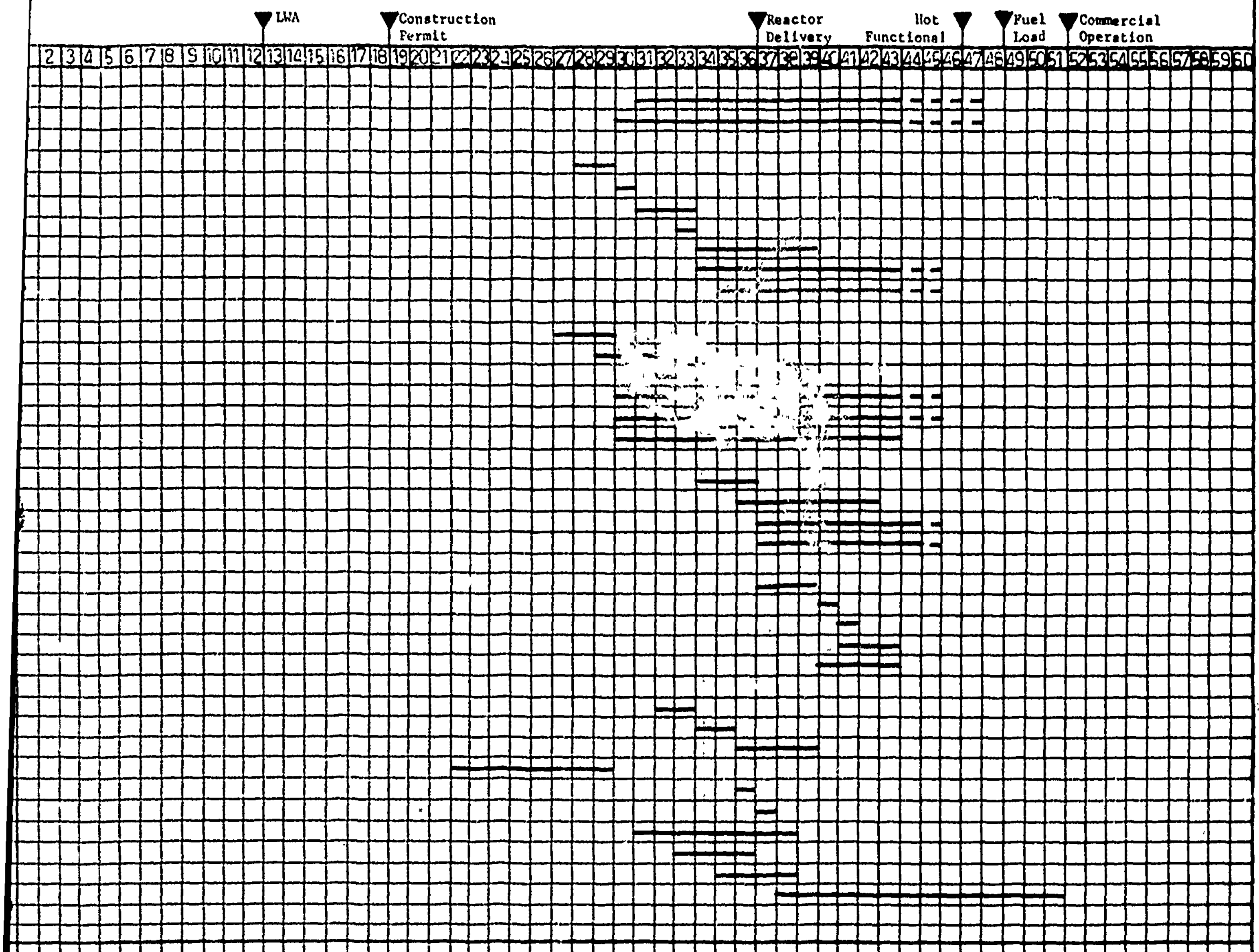
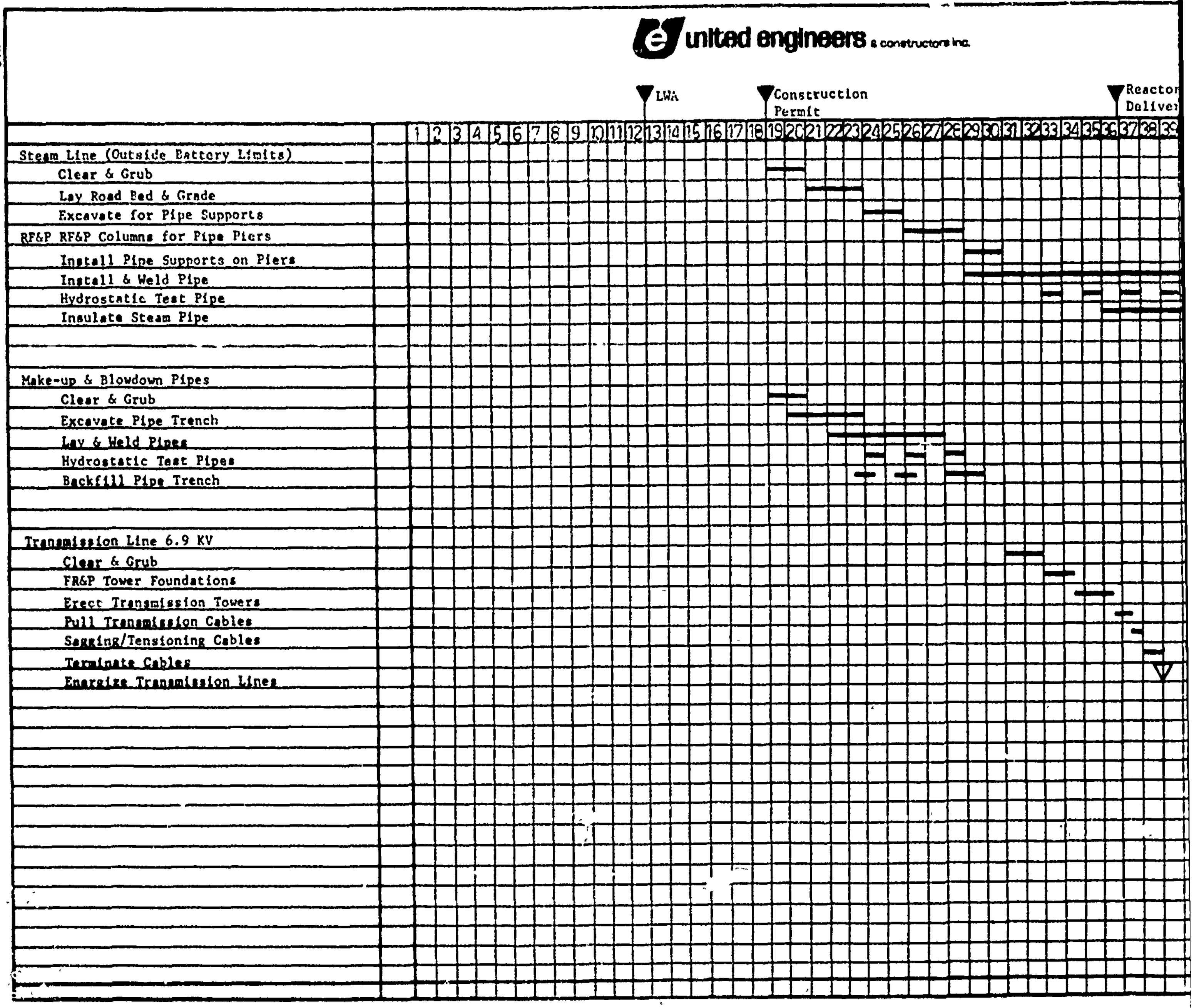


CONSTRUCTION SCHEDULE
PE-CNSG PLANT
FOR
DEPT. OF THE ARMY
RADFORD ARSENAL
RADFORD VIRGINIA

4-15-76

FIGURE A 5-1
PAGE 2 OF 3

PRELIMINARY



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PRELIMINARY

4-15

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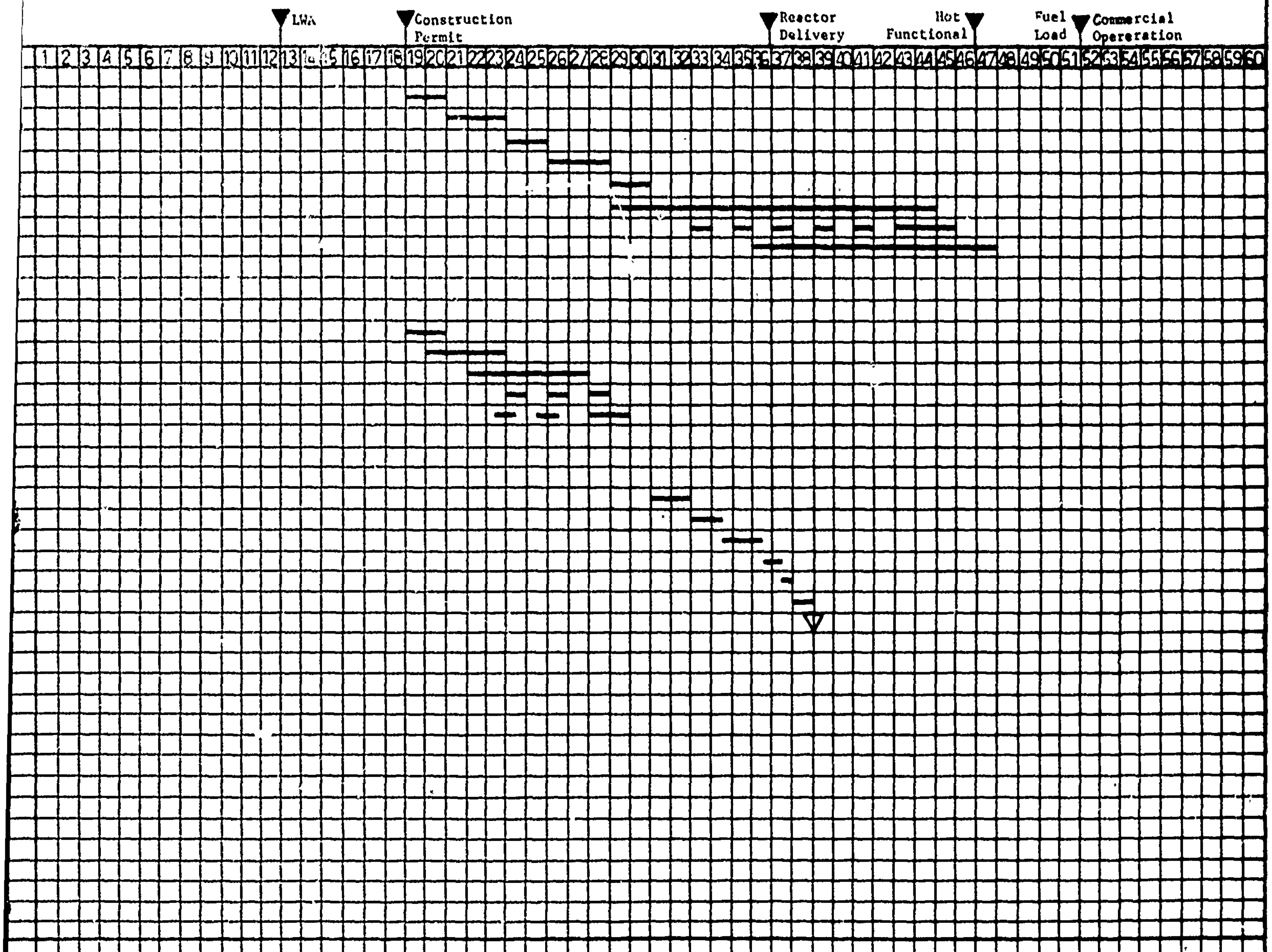


CONSTRUCTION SCHEDULE
PE-CNSG PLANT
FOR
DEPT. OF THE ARMY
RADFORD ARSENAL
RADFORD VIRGINIA

PRELIMINARY

4-15-76

FIGURE A5-1
PAGE 3 OF 3

APPENDIX 6

LICENSING LEAD T. E

APPENDIX 6, LICENSING LEAD TIME

Two licensing schedules have been prepared for the PE-CNSG plant in order to demonstrate the bounding conditions associated with the licensing process. The first, or upper bound schedule, is meant to depict a relatively long schedule in which no site data and no preliminary design exist at the start of the project. The second, or lower bound schedule, presents a relatively short schedule, but is not meant to show an absolute minimum duration. The lower bound schedule assumes site-related activities prior to contract award, in which the site has met the early site qualification criteria of Title 10, Code of Federal Regulations (CFR), Parts 2 and 50. These schedules are shown in Figures A and B respectively. Both the upper bound and lower bound assume compliance with 10 CFR 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Reprocessing Plants", instead of military quality assurance specifications; use of military specifications would tend to increase the ER and PSAR preparation time and the associated licensing schedule.

A third schedule, which reflects a more probable schedule for the PE-CNSG, and which has been assumed as licensing time elsewhere in this report, is discussed below as Schedule C.

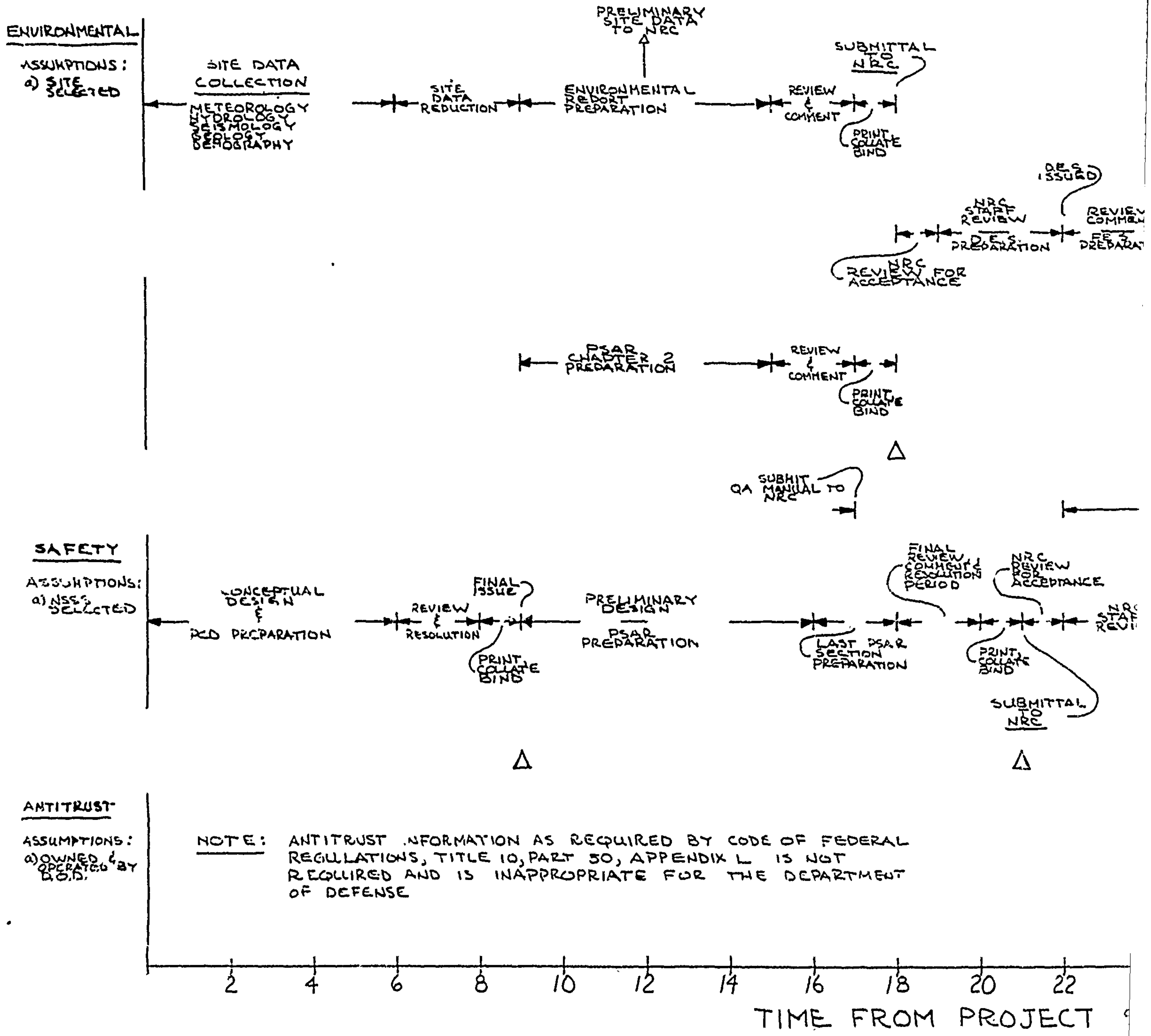
A. Upper Bound Schedule

Assumptions

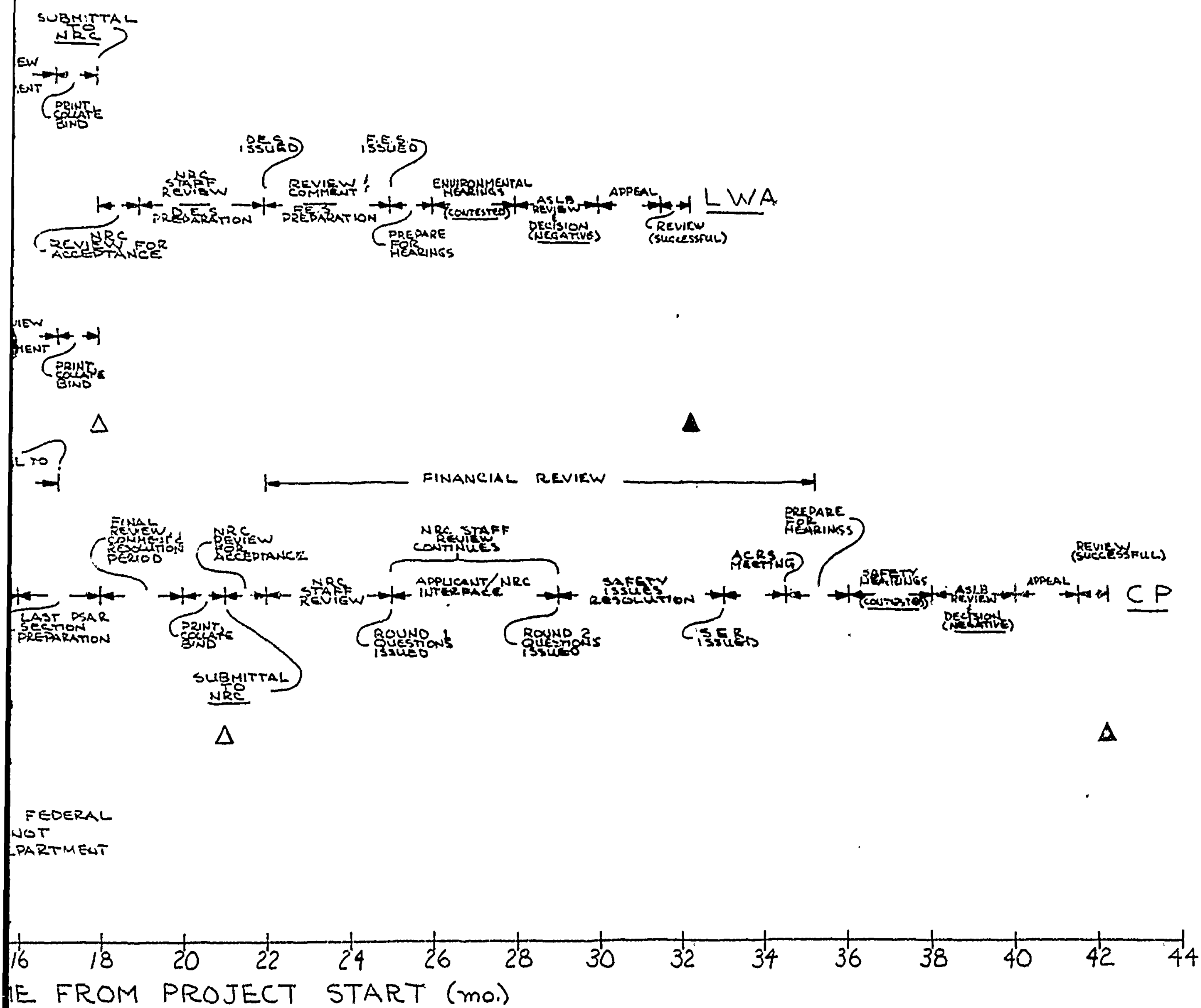
1. Site selected but no site data collection started.

2. NSSS selected; no plant of same design has gone through the licensing process.

LICENSING SCHEDULE-CNSG

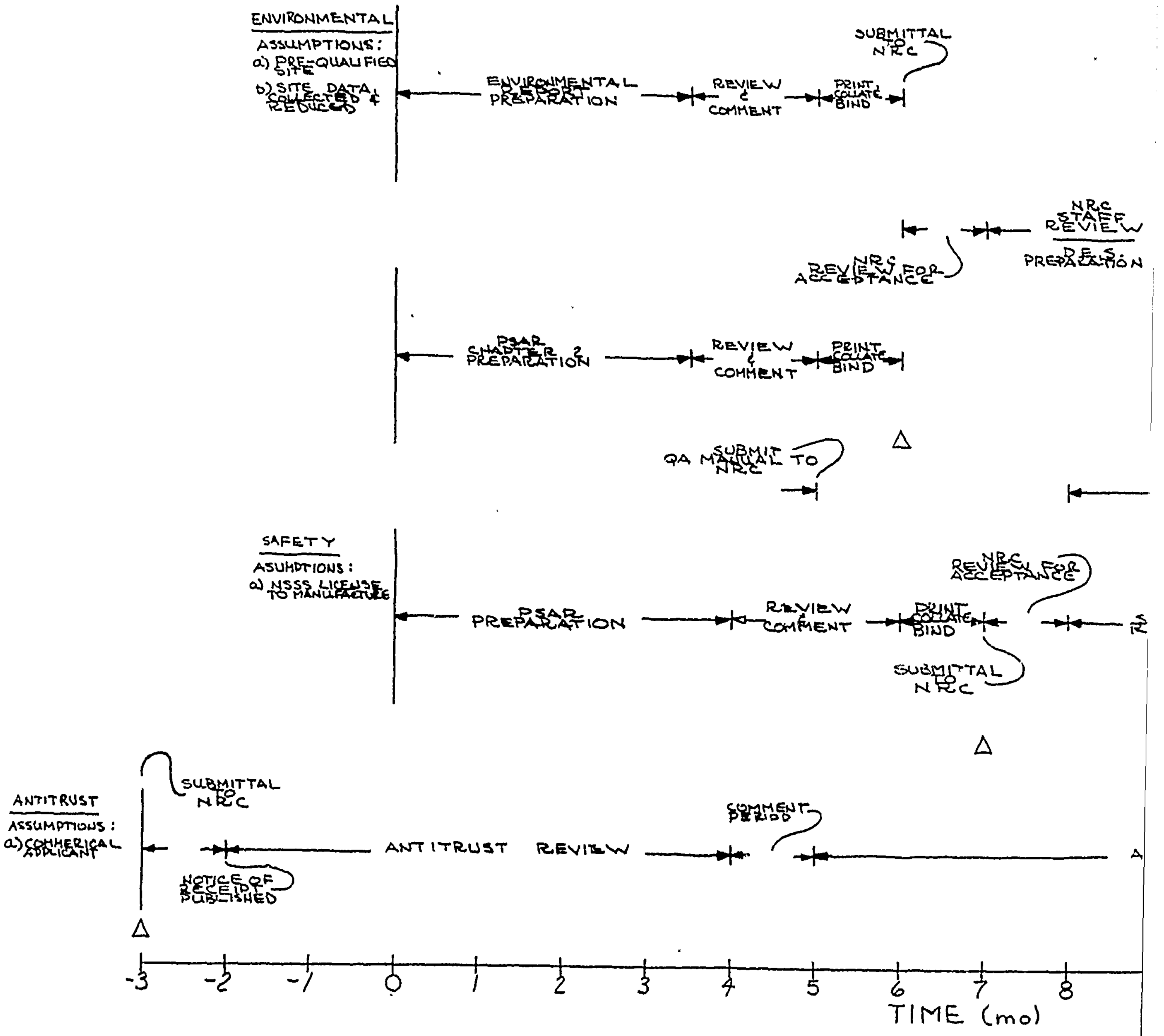


G SCHEDULE—CNSG (1st of a kind)

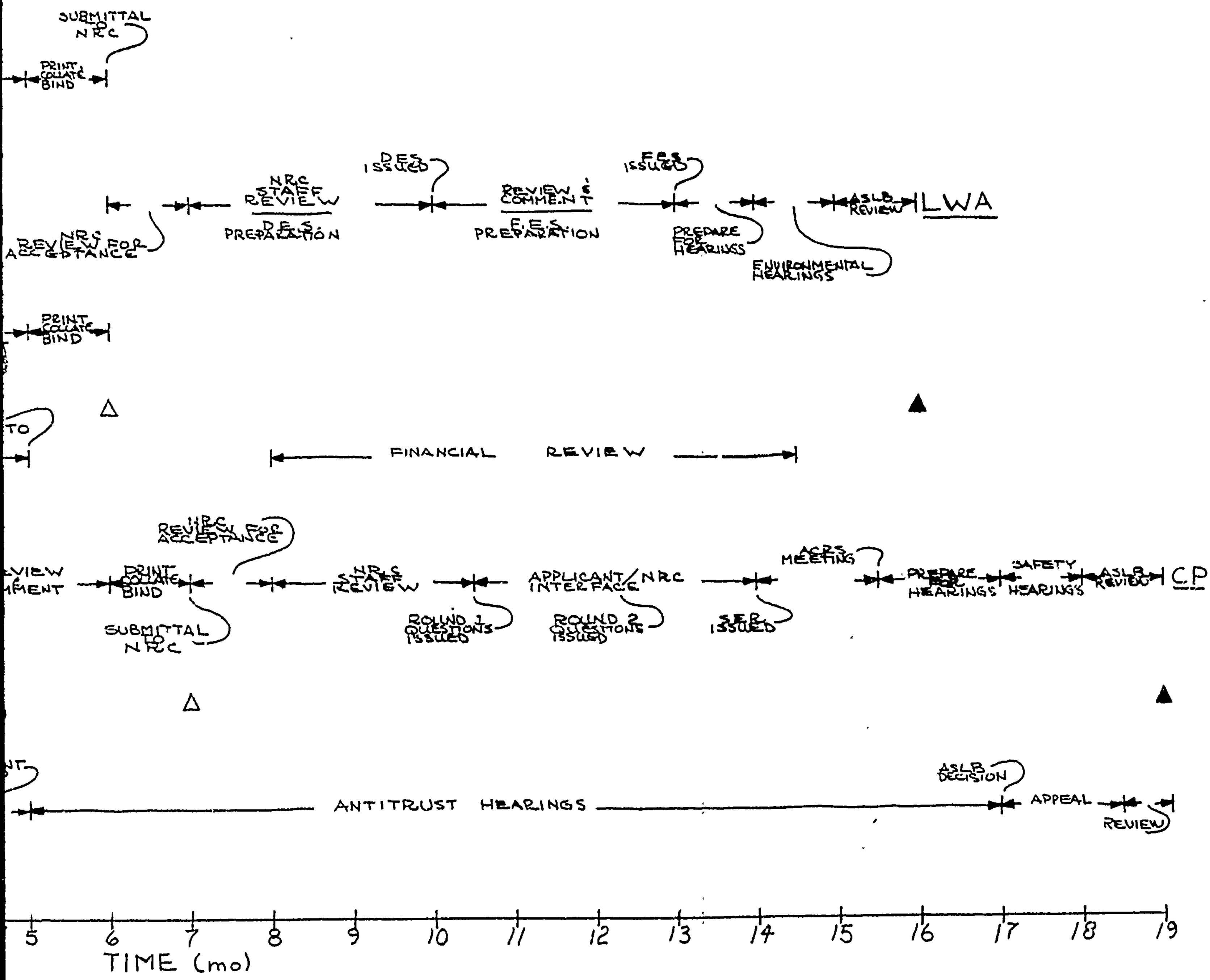


2

LICENSING SCHE



LICENSING SCHEDULE – CNSG (nth of a kind)



2

3. Assume DOD will have total ownership and operational responsibilities. DOD will not have to provide antitrust information. (In the event of commercial involvement, the antitrust schedule would be the same as that shown in Figure B.)

4. Both environmental and safety hearings are contested by intervenors thereby increasing the duration.

5. Both environmental and safety hearings result in a negative decision by the ASLB, are appealed, and decisions are reversed after appealed review.

6. PSAR and ER activities begin after the minimum 6 month site meteorological data has been reduced. It is assumed that meteorological data collection continues and a full year's (12 month) data is provided during the NRC review cycle.

7. Safety related questions, raised during the review cycle, such as nearby explosions of munitions, aircraft impact, etc., which are unique to a military installation, increase the duration of the review cycle.

B. <u>Lower Bound Schedule</u>

Assumptions

1. All site data have been collected, reduced and reviewed by NRC, and Site Qualification obtained.

2. NSSS vendor has obtained License to Manufacture.

3. Replication of BOP design as well as NSSS, eliminating preliminary design and requiring only site-specific items to be addressed in PSAR.

4. Environmental and safety hearings are not contested.

C. Accelerated Lower Bound CNSG Schedule

The following schedule utilizes some combination of the above assumptions, and which may be more applicable to the CNSG because it assumes that DOD will begin collection of site data prior to contract award.

Assumptions

1. The site is not prelicensed; however, DOD-ARMY has been assumed to collect 6 months meteorological data at 95% recoverability, as well as collect all other "ologies" at the time of ER preparation.

2. NSSS will be replicated from a previous design.

3. BOP will be a partial replicate; i.e., changes only due to site-related parameters and process heat feature of the PE-CNSG.

4. Some ER preparation begins before contract award, as well as obtaining radioactive source terms from a prototype facility.

5. An accelerated safety analysis effort, in which the meteorological data is meshed with the source terms (#4 above) to generated population and accident doses.

6. Public hearings are uncontested.

With the above assumptions, the licensing duration (to LWA) is expected to be 12 months.

APPENDIX 7

RELIABILITY - AVAILABILITY

APPENDIX 7

RELIABILITY - AVAILABILITY

The reliability of the PE-CNSG plant like all other plants depends on the reliability of its individual components and systems. The concept of reliability is first that a failure of a control element will not occur and, second, that if it does occur, it will not interrupt operation. This concept naturally is very closely tied in with that of availability, in the sense that a reliable system has a high degree of availability. NSSS availability is defined as the percent of total time that a nuclear unit is available to the utility for power operation.

The utility industry also sometimes defines plant availability as the time the generator was on line plus the time the plant was on standby available to produce electricity divided by the total time during the period. This definition was not used in this study.

Redundancy is another concept associated with availability. Redundant system components may take up the function of a system component that failed without an interruption in plant operation.

A comparison then between the PE-CNSG reliability and availability and that of a fossil-fired plant of similar size entails the following:

1. A detailed knowledge of their respective components and systems and their mode of operation.
2. The technological base of the PE-CNSG vs. fossil-fired plant, that is, are they both based on the same technology or is one system more advanced by virtue of past experiences and/or innovation.
3. Quality control and quality assurance of respective subsystems.
4. The reliability of their respective components.

5. The availability of fossil-fired plants of similar size and capacity which the PE-CNSG will be called for to compete with or to replace.

The CNSG* concept has been under conceptual or design development for nearly 15 years. The only operational application so far has been in the German nuclear ship Otto Hahn, which had a rather impressive record of achievement. The statistical data available is very small and is felt that the reliability and availability of the PE-CNSG must be inferred by comparison with other nuclear systems, after appropriate adjustment for size and differences in design and operation.

The PE-CNSG being a PWR system utilizes conventional PWR technology, materials, and design detail. It will be compared with other PWR units, which in terms of availability have fared better than BWR's in the past. The latter units were plaqued in 1975 (as in 1974) with cracks in stainless steel piping which were a big contributor to forced outages - a generic design problem associated with greater amounts of free oxygen in the primary coolant system.

The average unit availability factor of all nuclear plants as compiled by the AEC/NRC was 68.5% in 1974 and 72.2% in 1975, an improvement of 3.7% in availability. Furthermore, the data as of March 1975 shows that the cumulative availability of all U.S. commercial nuclear plants from their initial service dates was 72.4%. However, the cumulative availability of the NSSS was 3.7% better than for the plant as a whole, bringing NSSS availability to about 76.1%.

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*Here CNSG refers to the Commercial Ship Concept alone since no process steam or electricity is generated.

On the other hand, B&W, which is the prime contractor for the PE-CNSG-NSSS, reported that their six operational units in the U.S. had an average NSSS availability of near 80%. No B&W unit is or has been derated in the past. These statistics are encouraging for the ultimate availability of the PE-CNSG even though the statistical base especially for the B&W units is small both in the number of units and years of operation. It should also be noted, however, that the RC pump seal leakage problems and control rod drive stator problems associated with early B&W unit outages have been largely resolved, and future experience is expected to show higher availability.

In a report on nuclear power plant availability for 1973 issued by the AEC, statistics presented indicate an average plant availability factor for that year of 70% and an average capacity factor of 58%. The report analyzes 27 nuclear plants both BWR's and PWR's and show that 10 had availability factors of over 70%. An earlier conclusion in "Evaluation of Nuclear Power Plant Availability", OOE-ES-001, regarding attainment of and continued performance at availability factors equal to or greater than 80% after a three to four year break-in period were not substantiated by 1973 data. The average availability factor for plants in this age group was 67%. However, 1975 data as reported above, showed a marked improvement in these figures with the B&W units showing the highest availability.

A brief analysis was undertaken by UE&C to identify major components and systems of the PE-CNSG, both on the NSSS side and the BOP side as they relate to plant availability.

On the NSSS side, the PE-CNSG core consists of 57 fuel assemblies vs. the 205 for a typical large central station B&W unit having a maximum linear heat rate of 19.36 KW/ft and a core power of 3760 MWt. As a result of fewer number of fuel elements, there is a corresponding reduction in the failure possibility of these items.

During normal operation, 17 Control Rod Drive Mechanisms (CRDMs) are used in the PE-CNSG to raise, lower, or position control rod assemblies within the reactor core vs. 68 Control Rod Assemblies (CRAs) for the large PWR units, again resulting in a reduced failure probability for the PE-CNSG.

The reactor vessel of the PE-CNSG is a thick-walled carbon steel vessel with stainless steel cladding over the interior surfaces. It has a 157 inch inside diameter and a 34 ft-8 in. length from head to head. This compares with a 182" inside vessel diameter below the vessel supports and a 43'0" overall height for the large units for the reactor vessel alone. The utility steam generators also stand 75 ft. high between heads.

Again, the vessel in the PE-CNSG, even though it houses 12 steam generators, is smaller in diameter and height with possibly fewer welding parts; reducing the failure probability of this item. The reduction here is considered very minor, though. In the PE-CNSG design, however, the core is situated farther from the reactor vessel wall, and neutron bombardment and embrittlement of the Reactor Vessel during operation is significantly reduced.

The PE-CNSG employs 12 steam generators enclosed within the reactor vessel, as compared with two for the typical B&W utility units. This design

eliminates primary coolant piping outside the vessel, the source of BWR forced outages, as indicated earlier. It also eliminates much of the operational and analytical complexity associated with Emergency Core Cooling System design for PWRs.

The ratio of scheduled to forced outage for a typical steam generator is 0.35. Scheduled outages consist of planned and maintenance outages. Based on experience in 43 units in the period 1973-1975 and approximately 33 unit-years, the number of forced outages for a steam generator was 13, resulting in a total outage duration of 14,959.3 hours with an average, maximum and minimum duration of 1,150.7, 6,569.9 and 104 hours, respectively.

The failure rate per component year was given as 0.164. These results were reported by EPRI in a report titled, "Use of Nuclear Plant Operating Experience to Guide Productivity Improvement Programs".

The specifications of the PE-CNSG operation stipulate, however, that full rated power operation can be achieved without safety impairment with one steam generator inoperative. This requirement compensates for the increased probability of failure for the 12 steam generators on line vs. the two to four steam generators for other central station nuclear plants. Naturally, the same level of technological knowhow and manufacturing experience is assumed. The learning curve effect for the new CNSG generator design is small and can be neglected.

The PE-CNSG primary coolant pumps, by virtue of their smaller size, will result in a more reliable operation, i.e., a reduced or essentially no seal problem (as may occur in large pumps) is anticipated. Overall, then,

the reliability and availability of the CNSG-NSSS is expected to be higher than that of the B&W large units with an 85% availability considered a possibility. An 80% NSSS availability for the CNSG as a minimum can be considered a very probable number.

It should be pointed out, however, that the above availability factors are conservative because of the additional advantage of a shorter and more infrequent refueling schedule for the PE-CNSG.

Whereas, large central station nuclear power plants have refueling schedules approximately once every year lasting between three to six weeks depending on plant type and refueling option employed, the PE-CNSG's proposed refueling schedule will have an 18-day duration and will be performed every 18 months. This advantage by itself will add an extra availability factor ranging between 2% and 4%.

For the BOP portion of the PE-CNSG, the situation is a little more involved because of the dual role of electricity production and process steam generation that the PE-CNSG is expected to provide.

If emphasis on plant availability is for the process steam only, then because of fewer moving parts, simple configuration, and ease of operation the plant overall availability can approach that of the NSSS portion with very little additional downtime.

If the overall plant availability is based on both process steam and electrical generation, then the BOP availability of the CNSG will be penalized. This is because a study of the PE-CNSG equipment list reveals the

same type and complexity of equipment and systems as used for similar size plants for electricity productions. The parallel role of steam generation with the associated control and interface problems will further complicate the situation and decrease the overall plant availability.

In general, BOP components and systems for the CNSG can be assumed equivalent to those of large central station units except for two partially off-setting considerations. The first is that the components and systems in the PE-CNSG will not be as large or as numerous as those for the larger plants with a corresponding decrease in the overall failure probability. The second consideration is that due to first of a kind equipment and components in certain areas, namely the process steam system, the probability of failure as a result of insufficient design and/or retrofit will increase, thereby reducing the overall plant availability.

Conclusions

On the basis of our preliminary studies, it appears that the NSSS availability for the PE-CNSG including the refueling advantage can be assumed to be upwards of 83% and can reach as high as 85% or higher with a long term improvement as more PE-CNSG's come on line and greater experience gained with their operation.

For the PE-CNSG plant availability as a whole, including the BOP portion, overall availability can reach 80% to 85% if the emphasis is on process steam. If the emphasis is on both electric production and process steam, then an availability factor of greater than 80% will be difficult to achieve based on experience with nuclear plants now on line.

APPENDIX 8

ANNUAL OPERATING COSTS

Table A8-1
(Sheet 1 of 3)

ANNUAL OPERATING COSTS ($ x 10^3) FOR SYSTEM WITH NUCLEAR PLANT

Base Case: RAAP Operates At 45% of Peak Full Mobilization

Year of Operation	Fiscal Year	Annual Operating Costs (except for Purchased Power)	Purchased Power Costs	Total Annual Operating Costs	Discount Factor	Discounted Annual Operating Costs
1	1985	12,589	3,395	15,984	1.0	15,984
2	1986	13,344	3,565	16,909	0.909	15,370
3	1987	14,145	3,743	17,888	0.826	14,775
4	1988	14,994	3,930	18,924	0.751	14,212
5	1989	15,893	4,127	20,020	0.683	13,674
6	1990	16,847	4,333	21,180	0.621	13,153
7	1991	17,858	4,550	22,408	0.565	12,660
8	1992	18,929	4,777	23,706	0.513	12,161
9	1993	20,065	5,016	25,081	0.466	11,688
10	1994	21,269	5,267	26,536	0.424	11,251
11	1995	22,545	5,530	28,075	0.386	10,837
12	1996	23,898	5,807	29,705	0.350	10,397
13	1997	25,331	6,097	31,428	0.319	10,025
14	1998	26,851	6,402	33,253	0.290	9,643
15	1999	28,463	6,722	35,185	0.263	9,254

Table A8-1 (cont'd)
(Sheet 2 of 3)

Year of Operation	Fiscal Year	Annual Operating Costs (except for Purchased Power)	Purchased Power Costs	Total Annual Operating Costs	Discount Factor	Discounted Annual Operating Costs
16	2000	30,170	7,058	37,228	0.239	8,897
17	2001	31,980	7,411	39,391	0.218	8,587
18	2002	33,899	7,781	41,680	0.198	8,253
19	2003	35,933	8,170	44,103	0.180	7,939
20	2004	38,089	8,579	46,668	0.164	7,654
21	2005	40,375	9,008	49,383	0.149	7,358
22	2006	42,797	9,458	52,255	0.135	7,054
23	2007	45,365	9,931	55,296	0.123	6,801
24	2008	48,087	10,428	58,515	0.112	6,554
25	2009	50,972	10,949	61,921	0.102	6,316
26	2010	54,030	11,496	65,526	0.092	6,028
27	2011	57,272	12,071	69,343	0.084	5,825
28	2012	60,708	12,675	73,383	0.076	5,577
29	2013	64,351	13,309	77,660	0.069	5,358
30	2014	68,212	13,974	82,186	0.063	5,178
31	2015	72,305	14,673	86,978	0.057	4,958

Table A8-1
(Sheet 3 of 3)

Year of Operation	Fiscal Year	Annual Operating Costs (except for Purchased Power)	Purchased Power Costs	Total Annual Operating Costs	Discount Factor	Discounted Annual Operating Costs
32	2016	76,643	15,406	92,049	0.052	4,787
33	2017	81,242	16,177	97,419	0.047	4,579
34	2018	86,116	16,985	103,101	0.043	4,433
35	2019	91,283	17,835	109,118	0.039	4,256
			Total Present Worth Operating Costs			311,500

APPENDIX 9

Overpressure Calculations and Regulatory Guide 1.91

APPENDIX 9

OVERPRESSURE CALCULATIONS AND REGULATION GUIDE 1.91

In order to identify the overpressures that could result at site #3 from an accident along Virginia State Route 659 or along the Norfolk and Western Railroad, consideration was given to shipment of explosive materials and their equivalent TNT value. The assumptions made were:

1) RAAP does not ship expolsives along these transportation routes.

2) An equivalent 3-boxcar load (396,000 lbs) of TNT is postulated to detonate on the railroad 1200 feet east of the site.

3) An equivalent 1/4 truckload (10,750 lbs)* of TNT is postulated to detonate at a conservative distance of 360 feet east of the site.

4) The overpressure waves are not dampened by either vegetation or topography.

5) The probability of these postulated accidents occuring is greater than 10^{-7}.

The relationship for calculating the peak positive normal reflected pressure (in psi) is given by the following equation:

$$Z_G = R_G/W^{1/3}$$

*The 1/4 truckload is the approximate allowable net weight carried by an eighteen foot truck.

WHERE:

W = Charge Weight in Equivalent of TNT; lbs.

R_G = Radial Distance from Charge; feet

Z_G = Scaled Ground Distance; $ft/lb^{1/3}$

When Z_G, the Scaled Ground Distance, is determined, the Peak Positive Normal Reflected Pressure (Pr), can be determined from Figure 1 of Regulatory Guide 1.91.

For Case 1, 10,750 lbs of TNT on Route 659 at 360 feet, the scaled ground distance is 16.4 $ft/lb^{1/3}$ which results in a peak overpressure of approximately 10 psi.

For Case 2, 396,000 lbs of TNT on the Norfolk and Western Railroad at 1200 feet, the scaled ground distance is again 16.4 $ft/lbs^{1/3}$ which also results in an overpressure of approximately 10 psi.

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U.S. ATOMIC ENERGY COMMISSION

REGULATORY GUIDE

DIRECTORATE OF REGULATORY STANDARDS

REGULATORY GUIDE 1.91

EVALUATION OF EXPLOSIONS POSTULATED TO OCCUR ON TRANSPORTATION ROUTES NEAR NUCLEAR POWER PLANT SITES

A. INTRODUCTION

General Design Criterion 4, "Environmental and Missile Design Basis" of Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50, "Licensing of Production and Utilization Facilities," requires that nuclear power plant structures, systems, and components important to safety be appropriately protected against dynamic effects resulting from equipment failures which may occur within the nuclear power unit as well as events and conditions which may occur outside the nuclear power unit. These latter events include the effects of explosion of hazardous materials which may be carried on nearby transportation routes. This guide describes a method acceptable to the Regulatory staff for determining safe distances from a nuclear power plant to a transportation route over which explosive material (not including gases) may be carried.

B. DISCUSSION

In order to meet General Design Criterion 2, "Design Basis for Protection Against Natural Phenomena," of Appendix A to 10 CFR Part 50 with respect to tornadoes, the structures, systems, and components important to safety of a nuclear power plant must be designed to withstand the wind pressure and sudden internal pressure changes due to a design basis tornado without causing an accident, and without damage that would prevent a safe and orderly shutdown. Since the nuclear power plant is designed to safely withstand the design basis tornado described in Regulatory Guide 1.76, "Design Basis Tornado for Nuclear Power Plants," an explosion which produces a peak overpressure no greater than the wind pressure caused by the tornado should not cause an accident or prevent the safe shutdown of the plant. It should be noted that this applies only to the adequacy of the plant with respect to external dynamic overpressure. The potential effect of missiles from these explosions is still under study. This regulatory guide describes a method for determining distances from the power plant to a railway, highway, or navigable waterway beyond which any explosion that might occur on these transportation routes is not likely to have an adverse effect on plant operation or prevent a safe shutdown. Under these conditions, a detailed review of the transport of explosives on these transportation routes would not be required.

In establishing the distances referred to above, it is necessary to determine the dynamic wind pressure associated with the wind speed of the design basis tornado determined from Regulatory Guide 1.76 for each of the three regions of the contiguous United States. Table 1 presents the wind speeds for the three regions and the associated dynamic pressures calculated from $q = 0.002558V^2$ (this represents the kinetic energy per unit volume of moving air), where is the dynamic pressure in pounds per square foot and V is the maximum wind velocity in miles per hour (see Reference 1).

TABLE 1

DESIGN BASIS TORNADO
WIND SPEED CHARACTERISTICS

Region	*Maximum[a] Wind Speed, mph*	*Dynamic Wind Pressure, psi*	*Dynamic Wind Pressure, psf*
I	360	2.3	331.2
II	300	1.6	230.4
III	240	1.0	144.0

[a]The maximum wind speed is the sum of the rotational speed component and the maximum translational speed component.

The calculational method used to analyze the relationships of explosive charge to distance is first to

assume that the limiting peak overpressure due to an explosion is equal to the dynamic wind pressure resulting from a design basis tornado for a specific region and then to calculate the limiting distance beyond which the peak overpressure resulting from an explosion will not exceed the design dynamic wind pressure.

The conservative correlation for determining the peak explosion overpressure as a function of distance and weight of explosive (TNT) is the curve for peak reflected pressure, P_r, on Figure 1. As defined in Reference 2, the peak reflected pressure occurs when the shock wave impinges on a surface oriented so that a line which describes the path of travel of the wave is normal to the surface. This curve is taken from Figure 4.12 of Reference 2 with some of the symbols modified.

Table 1 gives 2.3 psi as the external dynamic wind pressure due to a design basis tornado in Region I. From Figure 1, the scaled distance, Z_G, corresponding to a peak reflected pressure of 2.3 psi is found to be 41. The following function of distance and explosive charge is then determined for Region I:

$$R_G = 41W^{1/3}$$

Similarly, the correlations for the remaining regions are:

Region II $R_G = 55W^{1/3}$

Region III $R_G = 80W^{1/3}$

where R_G is the distance in feet from an exploding charge of W pounds of TNT. Reference 3 provides the TNT equivalents of other types of explosives. For hazardous materials not listed in Reference 3, the applicant should substantiate the derivation of the TNT equivalent used.

The maximum probable hazardous cargo for a single highway truck is approximately 43,000 pounds (equivalent TNT). The distance beyond which an exploding truck will not have an adverse effect on plant operations or will not prevent a safe shutdown is indicated in Figures 2, 3, and 4 for Regions I, II, and III, respectively.

Similarly, the maximum explosive cargo in a railroad box car is approximately 132,000 pounds (equivalent TNT). The distance beyond which an exploding railroad box car will not have an adverse effect on plant operations or will not prevent a safe shutdown is shown in Figures 2, 3, and 4. In this case, it is also necessary to consider the possible effects of a simultaneous explosion of connected box cars. For illustrative purposes an evaluation for three box cars is provided. The distance beyond which three box cars exploding simultaneously will not have an adverse effect on plant operations or will not prevent a safe shutdown is shown on Figures 2, 3, and 4. If there is a significant probability that more than three box cars of explosives will pass by the nuclear power plant in one shipment, further evaluation by the applicant will be necessary.

The largest probable quantity of explosive material transported by ship is approximately 10,000,000 pounds (equivalent TNT). The distance from the shipping channel beyond which such an explosive charge will have no adverse effect on plant operations or prevent a safe shutdown is shown on Figures 2, 3, and 4.

Table 2 summarizes the results of the minimum distances shown on Figures 2, 3, and 4 for the maximum postulated shipments by truck, railroad boxcar, multiple railroad boxcars, and ship.

TABLE 2

DISTANCES (IN FEET) TO EQUIVALENT TORNADO OVERPRESSURES

Tornado Region	*43,000-lb Truckload*	*132,000-lb 1-Boxcar Load*	*396,000-lb 3-Boxcar Load*	*10,000,000-lb Shipload*
I	1500	2100	3000	9000
II	1900	2800	4000	11500
III	2800	4000	5800	17000

C. REGULATORY POSITION

In the design of nuclear power plants, the ability to withstand the possible effects of explosions occurring on nearby transportation routes should be considered relative to the effects of the design basis tornado.

When carriers that transport explosives can approach vital structures of a nuclear facility no closer than the distances indicated in Figures 2, 3, and 4, no further consideration need be given to the effects of external dynamic overpressure in plant design. If transportation routes are closer to structures and systems important to safety than the distances indicated in Figures 2, 3, and 4, the applicant should show that the risk to the public is acceptably low on the basis of, for example, low probability of explosions or structural capability for safety-related structures to withstand explosions.

D. IMPLEMENTATION

The purpose of this section is to provide guidance to applicants and licensees regarding the Regulatory staff's plans for utilizing this regulatory guide.

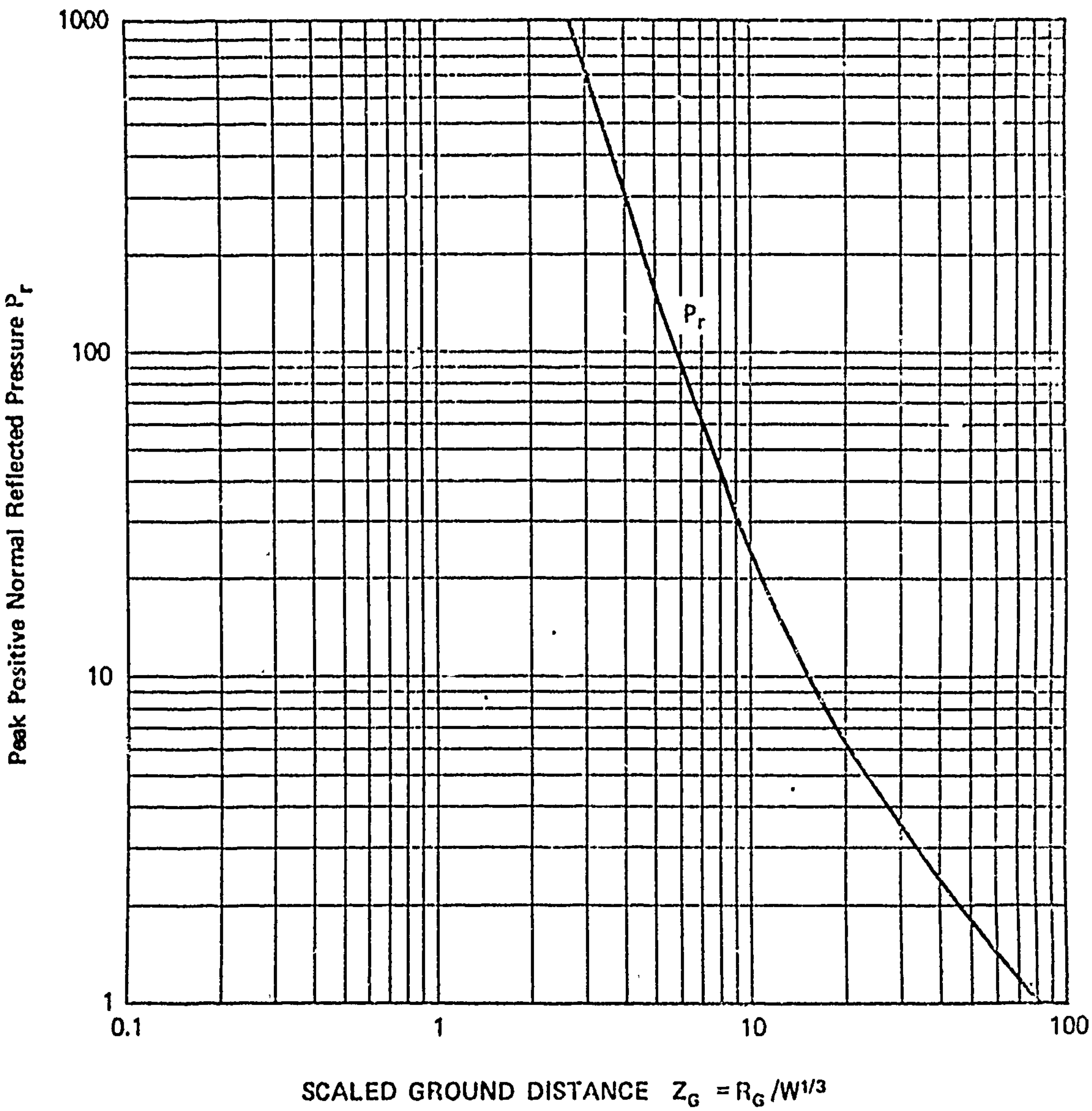
Except in those cases in which the applicant proposes an alternative method for complying with specified portions of the Commission's regulations, the method described herein will be used in the evaluation of construction permit applications docketed on or after March 14, 1975.

REFERENCES

1. "Wind Forces on Structures" Paper No. 3269, ASCE Transactions, Vol. 126, Part II, 1961.

2. Department of the Army Technical Manual TM 5-1300, "Structures to Resist the Effects of Accidental Explosions," June 1969.

3. Annals of the New York Academy of Science, Volume 152, Article 1, "Prevention of and Protection Against Explosion of Munitions, Fuels and other Hazardous Mixtures." Part 4, October 28, 1968.



P_r = Peak Positive Normal Reflected Pressure, psi
W = Charge Weight, lb
R_G = Radial Distance from Charge, ft
Z_G = Scaled Ground Distance, $ft/lb^{1/3}$

Figure 1

Peak Positive Normal Reflected Pressure for Hemispherical TNT Surface Explosion at Sea Level

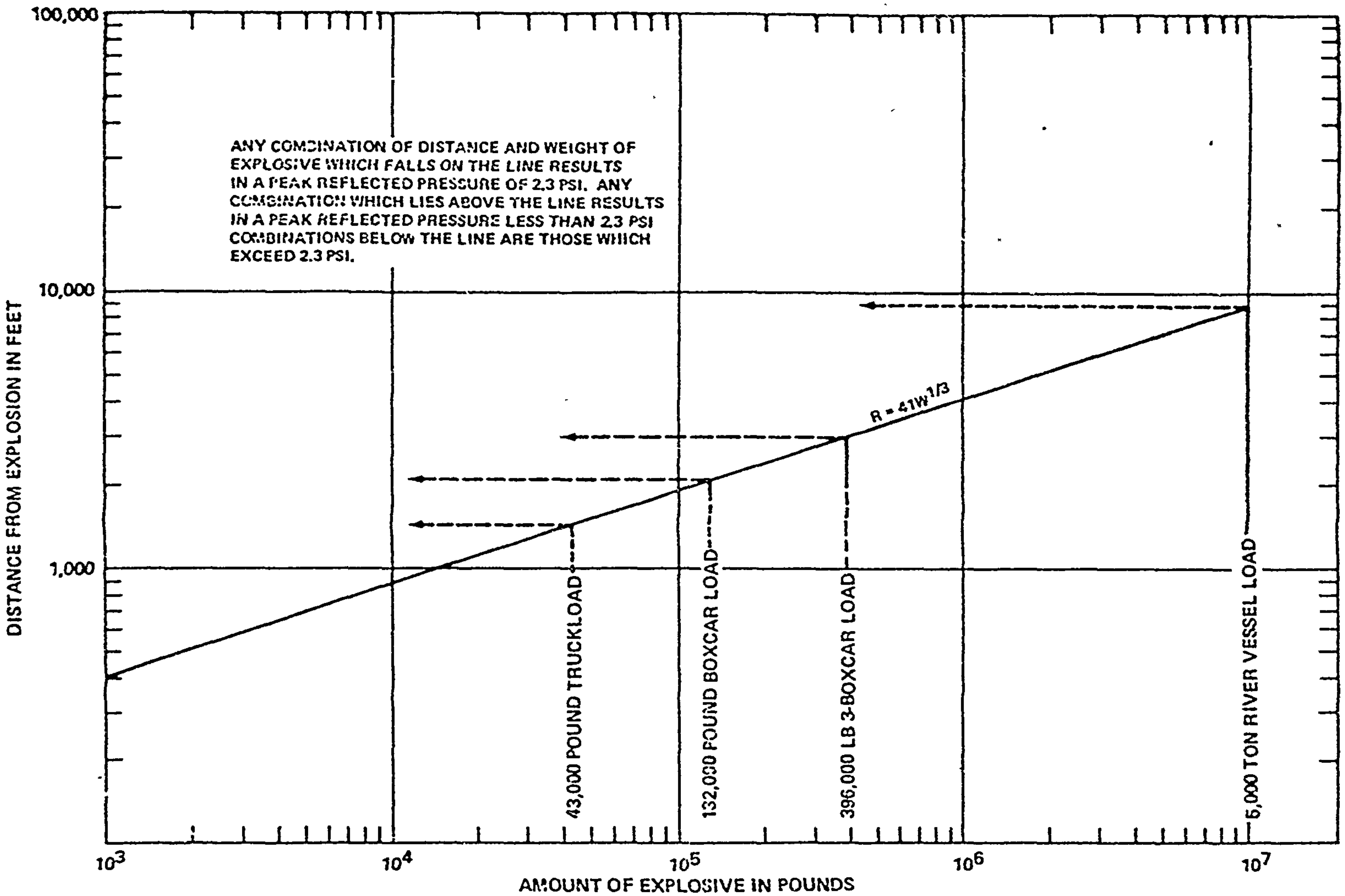


FIGURE 2 APPLICABLE TO TORNADO REGION I

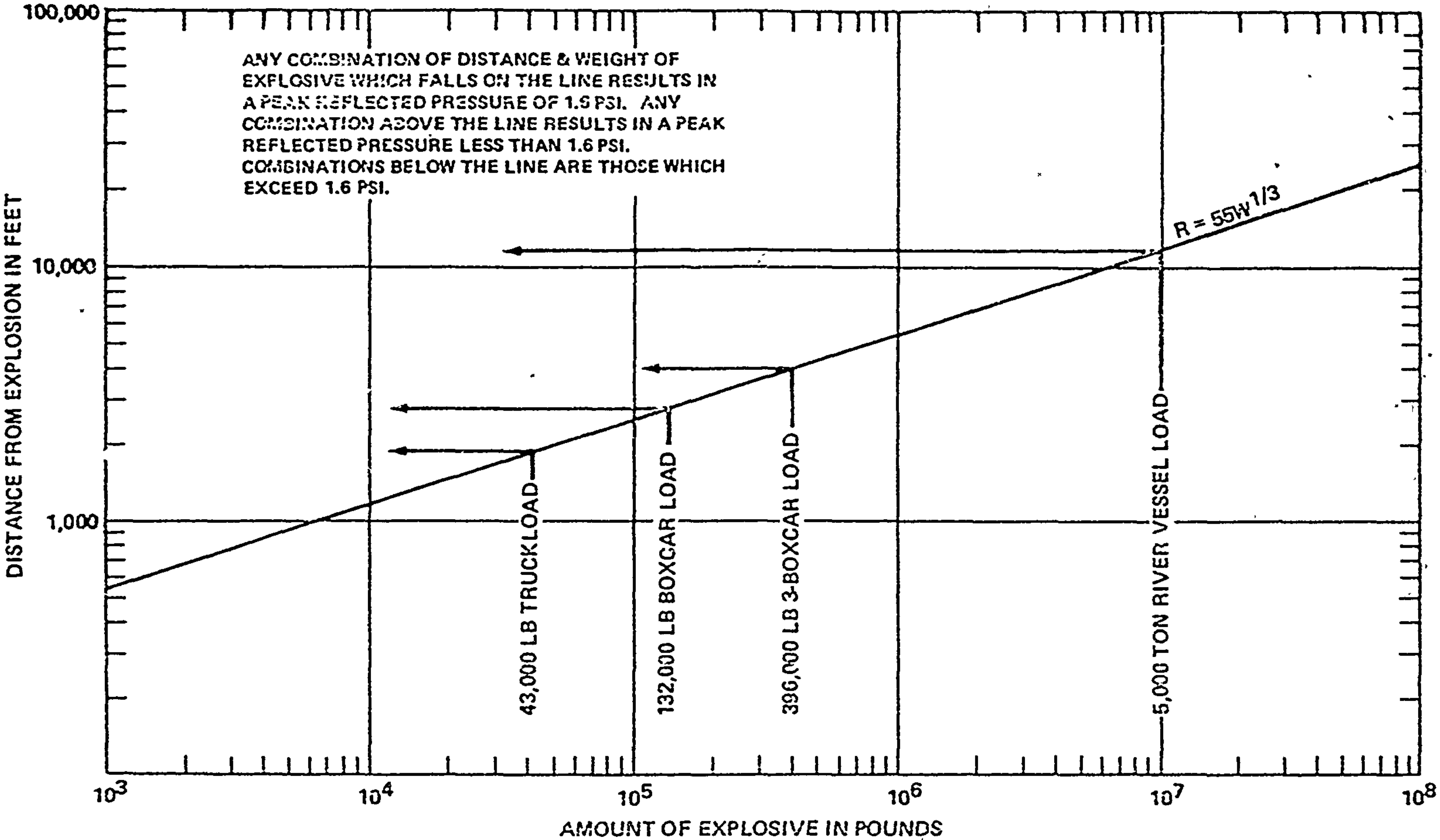


FIGURE 3 APPLICABLE TO TORNADO REGION II

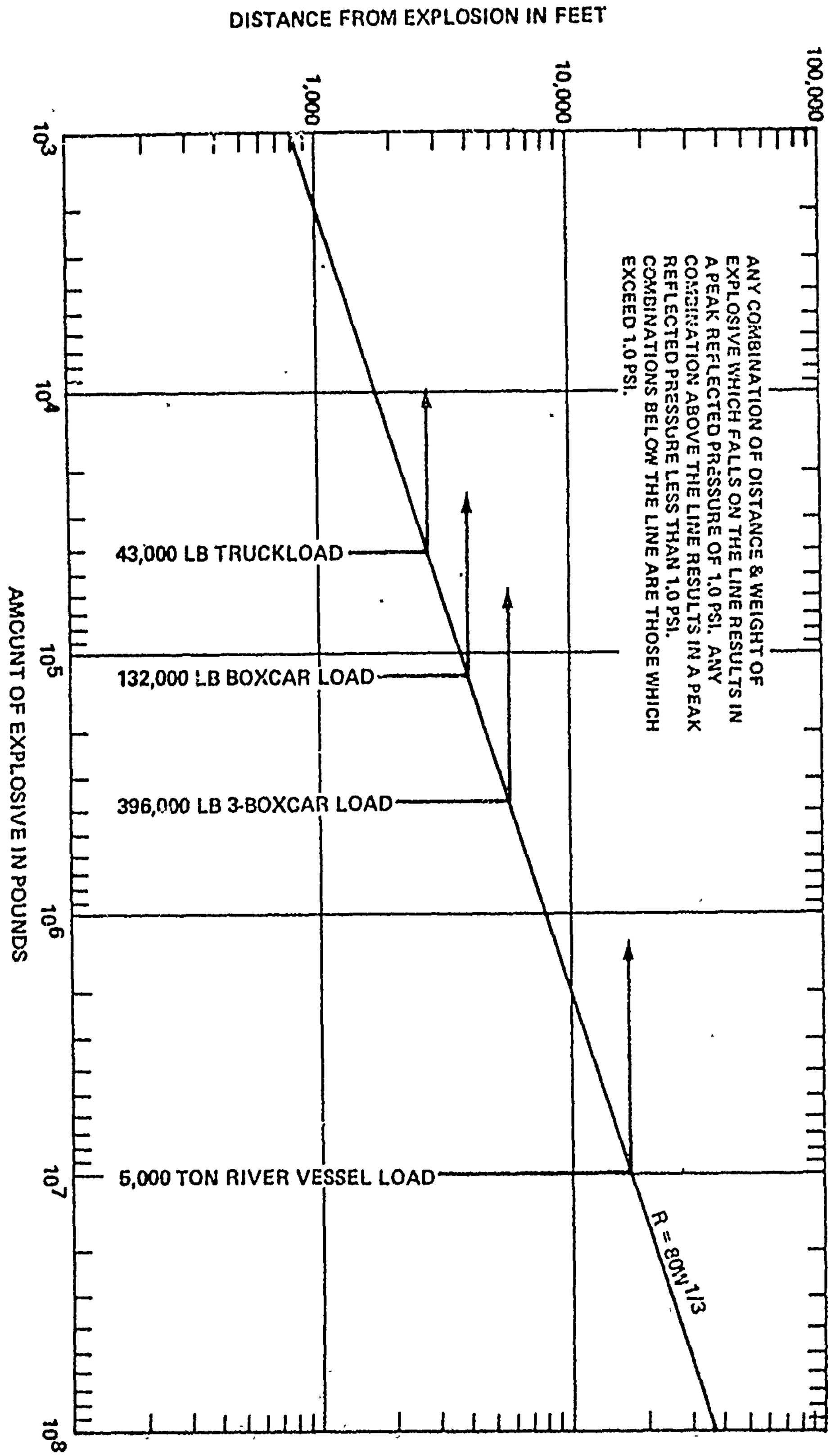


FIGURE 4 APPLICABLE TO TORNADO REGION III

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